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ANG PAMPULET

AMCP 706-177

ENGINEERING DESIGN HANDBOOK

EXPLOSIVES SERIES
PROPERTIES OF EXPLOSIVES
OF MILITARY INTEREST

HEADQUARTERS, U.S. ARMY MATERIEL COMMAND

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ENGINEERING DESIGN HANDBOOK

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

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^{*}This pamphlet supersedes AMCP 706-177, 22 March 1967, including Change 1, 20 December 1967.

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PREFACE

The Engineering Design Handbook Series of the Army Materiel Command is a coordinated series of handbooks containing basic information and fundamental data useful in the design and development of Army materiel and systems. The handbooks are authoritative reference books of practical information and quantitative facts heipful in the design and development of Army materiel so that it will meet the tactical and technical needs of the Armed Forces.

AMCP 705-177, Properties of Explosive: of Military Interest, is one of a series on Explosives. One hundred and ten explosive compounds or mixtures are fisted herein, alphabetically, with their properties, including composition variations. These explosives were selected because of their current or probable application to military use.

The tabulated data reflect the results of tests, and were inst compiled for publication at Picatinny Arsenal, Dover, New Jersey, by M. R. Tomlinson, Jr. These data were later revised by Oliver E. Sheffield, also of Picatinny Arsenal. for the Engineering Handbook Office of Duke University, prime contractor to the Army Matamiel Command.

The Handbooks are readily available to all elements of AMC, including personnel and contractors having a need and/or requirement. The Army Materiel Command policy is to release these Engineering Design Handbooks to ther DOD activities and their contractors and to other Government agencies in accordance with current Army Regulation 70-31, dated 9 September 1966. Procedures for acquiring these Handbooks follow:

a. Activities within AMC and other DOD agencies order direct on an official form from:

Commanding Officer Letterkenny Army Depot, ATTN: AMXLE-ATD Chambersburg, Pennsylvania 17201

b. Contractors who have Department of Defense contracts should submit their requests through their contracting officer proper justification to the address listed in par. a.

c. Government agencies other than DLD having need for the Handbooks may submit their requests directly to the address listed in par. a or to:

Commanding General U. S. Army Materiel Command ATTN: AMCAM-ABS Washington, D. C. 20315

d. Industries not having Government contracts (this includes colleges and Universities) must forward their requests to:

Commanding General U. S. Army Materiel Command ATTN: AMCRD-TV Washington, D. C. 20315

e. All foreign requests must be submitted through the Washington, D. C. Embassy to:

Assistant Chief of Staff for Intelligence Foreign Liaison Office Department of the Army Washington, D. C. 20310

All requests, other than those originating within DOD, must be accompanied by a valid justification.

Comments and suggestions on this handbook are welcomed and should be addressed to Army Research Office-Durham, Box CM, Duke Station, Durham, North Carolina 27706.

ABBREVIATIONS AND SYMBOLS

```
approximately. This symbol is used before numbers.
۸C
                        Advisory Council on Scientific Research and Develop-
                        ment, Great Britain.
American Chemical Society.
American Tron and Steel Institute.
Liebig's Annalen der Chemie.
ACS
AISI
Ann
Ann chim phys
                        Annales de chimie et de physique.
                        armor-piercing.
Aberdeen Proving Ground.
APG
                        atmosphere; atmospheric pressure.
atz
                        Beilstein Organische Chemie, 4th Edition.
Berichte der Deutschen Chemischen Gesellschaft.
Beil
Ber
                        British Intelligence Overseas Service or Objective
Subcommittee, Group 2, Halstead Exploiting Center.
Bureau of Mines, United States Department of Interior.
BIOS GP2-HEC
BM
Bull Soc caim
                        Bulletin de la societé chimique de France. Chemical Abstracts.
CA
calc
                        calculated.
Cham Ket Eng
                        Chemical and Metallurgical Engineering.
                        Chimie et Industrie.
Comptes rendus hebdomadaires des geances de
Chim et Ind
Comp read
                               l'Academie des Sciences (Parie).
                        centipoise.
CP
CR
                        tomptes rendus hebiomadaires des seances de l'Academie des Sciences (Paris).
dec
                        decomposes.
                        difference in heat (i.e., heat evolved) by decomposition. Deutsches Reichspatent.
ΔH
DRP
                        Deutsches Reichspatent.
modulus of elesticity or "Young's modulus"; longitudinal
stress/change in length; (force/area)/(elongation/
length); expressed in lb/inch2.
same as 2, but expressed in dynes/cm2.
E
Gazz chim ital
                        Gazzetta Chimica Italiana.
                        general purpose.
high explosive.
high explosive antitank.
HE
HEAT
                        Industrial & Engineering Chemistry.

Journal of the American Chemical Society

The Journal of the Society of Chemical Industry (London).

Journal of the Chemical Society (London).
Ind Eng Chem
J Am Chem Soc
  Chem Ind
J Chen Soc
                        Journal of the Franklin Institute.
  Prank Inst
J Ind Explo-
sives Soc
J prakt Chem
                        Journal of the Industrial Explosives Society (Japan).
                        Journal für praktische Chemie.
                        lesd az'de
Land-Bornst
                        Landolt-Bornstein Physikalish-Chemische Tabellen,
                               5th Edition (Berlin).
                        Monatshefte für Chemie (Wein).
Kém pondr
                        Mémorial des poudres et salpêtres (Paris).
                        milligram.
```

ABBREVILTIONS AND SYMBOLS (cont'd)

```
sinimum.
min
                              milliliter.
ml
m/s
                             meters per second.
molecular weight.
Bureau of Ordnanco (U. S. Savy)
nitrocellulose.
MW
NAVORD
NC
n D 20
                              index of refraction, with D band of sodium as light
                              source, at twenty degrees centigrade.
National Defense Research Committee.
Hational Fireworks Ordnance Corporation.
MDRC
MYOC
                             nitr glycerin.
U. S. Maval Ordnance Laboratory, White Oak, Silver
MG
NOL
                              Spring, Maryland.
U. S. Haval Ordnance Test Station, China Lake, Calif.
Mational Research Council.
ROTS
NRC
OB
                              oxygen balance.
                              Ordnance Committee Minutes.
Office of Scientific Research and Development
OCH
OSED
                              Picatinny Arsenal.
Picatinny Arsenal Technical Report.
Philosophical Transactions of the Royal Society of
PA
PATR
Phil Trans
                             London.
Poggendorf's Annalen der Physik.
Proceedings of the Royal Society of London.
Recueil des travaux chimiques des Pays-Bas.
Pogs Ann
Proc Roy Soc
Rec trav chim
                              relative humidity.
Report of Investigation.
RH
RI
SAE
                              Society of Automotive Engineers.
                              semi-armor-piercing.
SAP
                              solution.
soi
Spec
std dev
                               Specifications.
Spec Specifications.

std dev standard deviation.

TM Technical Hanual, Department of the Army.

joint publication, as a TM and as a Department of the Air Force Technical Order.

Trans Farad Soc Transactions of the Faraday Society vacuum stability.
                              Zeitschrift für angewandte Chemie.

Leitschrift für anorganische und allgemeine Chemie.

Zeitschrift für das gesamte Schiess und Sprengstoff-

wessen (Munchen).
Z angew Chem
Z anorg Chem
Z ges Schiess-
   Sprengstofiw
                               atoms of oxyger per second.
```

PROPERTIES OF EXPLOSIVES OF MILITARY INTEREST

INTRODUCTION

1. PREDOMINATILY A REPORT OF STANDARD TESTS. No effort was made to cover all the existing literature, either open or classified security information, on any explosive. Sather, the main resource has been reports from facilities using standard of well-known test procedures.

2. ORIGIN. Compilation of data resulting in this handbook was undertaken by Picatinny Arsenal personnel who desired to provide a manual tabulating the characteristics of emplosives, based on tests, with regard to current, and possible future, interest. The first resulting Picatinny Arsenal publication was dated 20 June 1949. Revision 1, PA Technical Report No. 1740, dated April 1958, with revisions, provides the data used herein.

3. SCEPA. Tabulated data of tests on one hundred and ten explosive compounds or mixtures include sensitivity to friction, impact, heat; performance characteristics or effectiveness in weapons; physical and chemical properties; and method of preparation, synthesis or manufacture, with comments on historical origin, and supplementary references.

REFERENCE MOTATIONS AND SOURCES. The references, as to sources of data or for more details in methods of testing, have been listed, when available, at the end of each section devoted to a given emplosive compound, explosive mixture, or explosive ingredient. Where no reference is given, it can be assumed that these data represent typical values obtained by standard procedures. When available any reference should be consulted for more details in interpreting test data.

Also there are listed Picatinny Arsenal Technical Reports which contain **dditional information on the particular explosive. These report numbers are given in ascending order, in columns corresponding to their terminal digits, and in accordance with the "Uniterm Index" prepared for Picatinny Arsenal by Documentation Incorporated under Contract DAI-36-034-501-ORD-(P)-42 (1955).

5. EXPLANATION OF TERMS AND METRODS OF TESTING. Data are tabulated herein on three form-type pages, in the following sequence of headings. Many of these terms are self-explanatory.

a. First tabular page.

- (1) Name of the explosive in each instance.
- (2) "Composition."
- (3) "Impact Sensitivity, 2 Kg Wt."
 - (a) Impact sensitivity test for solids. (a)*

A sample (approximately 0.02 gram) of explosive is subjected to the action of a falling weight, usually 2 kilograms. A 20-milligram sample of explosive is always used in the Bureau of Mines (BM) apparatus when testing solid explosives. The weight of sample used in the Picatinny Arsenal (PA) apparatus is indicated in each case. The impact test value is the minimum

^{*}Reference publications (a through q), applying to this introduction, are listed at the end of the introduction.

neight at which ar least one of 10 trials results to exclusion. For the EM apparatus, the unit of height is the centimeter; for the PA apparatus, it is the inch. In the former, the explosive is held between two flat, parallel hardened (C 63 x 2) steel surfaces; in the latter case, it is placed in the depression of a small steel dis-cup, capped by a thin brass cover, in the center of which is placed a slotted-vented-cylindrical steel plug, slotted side down. In the held apparatus, the impact impulse is transmitted to the sample by the upper flat surface, in the PA, by the vented plug. The main differences between the two tests are that the PA test (1) involves greater confinement, (2) distributes the translational impulse over a smaller area (due to the inclined sides of the dis-cup cavity), and (3) involves a frictional component against the inclined sides).

The test value obtained with the PA apparatus depends, to a marked degree, on the sample density. This value indicates the hazard to be expected on subjecting the particular sample to an impact blow, but is of value in assessing a material's inherent sensitivity only if the apparent density (charge weight) is recorded along with the impact test value. The values tabulated harein were obtained on material screened between 50 and 100 mesh, U. S. Standard Screens where single component explosives are involved, and through 50 mesh for the mixtures.

(b) Impact sensitivity test for liquids. (b)

The PA Impact Test for liquids is run in the same way as for solids. The die-cup is filled and the top of the liquid meniscus adjusted to coincide with the plane of the top rim of the die-cup. To date, this visual observation has been found adequate to assure that the liquid does not wot the die-cup rim after the brass cap has been set in place. Thus far the reproducibility of data obtained in this way indicate that variations in sample size obtained are not significant.

In the case of the BM apparatus, the procedure that was described for solids is used with the following variations:

- 1. The weight of explosive tested is 0.007-gm.
- 2. A disc of desiccated filter paper (Whatman No. 1) 9.5-millimeter diameter; is laid on each drop, on the anvil, and then the plunger is lowered on the sample absorbed in the filter paper.
 - (4) "Friction Pendulum Test." (c)

A 7.0-gm sample of explosive, 50-100 mesh, is exposed to the action of a steel, or fiber, shoe swinging as a pendulum at the end of a long steel rod. The behavior of the sample is described qualitatively to indicate its reaction to this experience, i.e., the most energetic reaction is explosion, and in decreasing order of severity of reaction: snaps, cracks, and

(5) "Riffle Bullet Impact Test." (d)

Approximately 0.5-pound of explosive is leaded in the same manner as it is leaded for actual use: that is, east, pressed, or liquid in a 3-inch pipe nipple (2-inch inside diameter, 1/10-inch wall) closed on each end by a cap. The leaded item, in the standard test, contains a small air space which can, if desired, be filled by inserting a wax pluy. The leaded item is subjected to the impact of a caliber .30 bullet fired perpendicularly to the long axis of the pipe nipple, from a distance of 90 feet.

(6) "Explosion Temperature." (a)

A 0.02-gm sample (0.01-gm in the case of initiators) of explosive, loose loaded in a No. 8 blasting cap, is ammersed for a short period in a Wood's metal bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 seconds, and the behavior of the sample is indicated by "Explodes" or "Ignites" or "Decomposes" placed beside the value. Where values were available for times other than 5 seconds, these have been included. For 0.1-second values, no cap was used, but the explosive was placed directly on Wood's metal bath, immediately after cleaning. The value 0.1 second is estimated, not determined, and represents an interval regarded as instantaneous to the observer's eye. Dashes indicate no action-

(7) "75°C International Heat Test." (a)

A 10-gm sample is heated for 48 hours at 75° C. The sample after this exposure is observed for signs of decomposition or volatility.

(8) "100°C Heat Test." (a)

A 0.6-gm sample is heated for two 48-hour periods at 100° C. It is also noted whether exposure at 100° C for 100 hours results in explosion.

(9) "Flammatility Index." (h)

The measure or the likelihood that there charge will catch fire when exposed to flames is the index of flammability. The test is made by bringing an oxyhydrogen flame to bear on the explosive. The maximum time of exposure which gives no ignition in 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of flammability is 100 divided by the mean of the two times in seconds. The most flammable substances have high indices, e.g., 250.

(10) "Hygroscoricity."

A 5- to 10-gm sample is exposed for hygroscopicity under the stated conditions, until equilibrium is attained, or in cases where either the rate is extremely low, or very large amounts of water are picked up, for the stated time. The sample, if solid, is prepared by sieving through a 50 and on a 100 mesh screen.

(11) "Volatility."

A .3-gm sample is exposed for volatility under the stated conditions. The sample if solid is prepared by sieving through a 50 and on a 100 mesh sieve.

(12) "Molecular Weight."

The molecular weight (MW) of a mixture can be calculated from the equation

MV of mixture =
$$\frac{100}{\frac{8}{mv_1} + \frac{b}{mv_2} + \frac{c}{mv_3} + \frac{n}{mv_n}}$$

where a, b, c and s are the weight purcents of the components, and mv_1 , mv_2 , mv_3 and mv_n their corresponding molecular weights.

(13) "Oxygen Balance."

The caygon balance (OB) is calculated from the empirical formula of a compound in percentage of caygon required for complete conversion of carbon to carbon dioxide (or carbon monoxide) and hydrogen to water. When metal is present the reactions are assumed to occur in the following

Metal + 0
$$\longrightarrow$$
 Metal Oxide
C + H₂O \longrightarrow CO + N₂
CO₂ + H₂ \longrightarrow CO + H₂O
2CO + O₂ \longrightarrow 2CO₂

Procedure for valculating oxygen balance is to determine the number of gramatoms of oxygen which are excess or deficient for 100 grams of a compound. This number multiplied by the atomic weight of oxygen gives

the oxygen belance: 1600 (2X + $\frac{Y}{Z}$ - Z)

 \pm molecular weight of compound = oxygen balance to CO_2 and H_2O , where X = atoms of urbon, Y = atoms of oxygen. The oxygen balance of a mixture is equal to the sum of the percent composition times the oxygen balance for each component.

The cerbon/hydrogen (C/E) ratio is calculated as follows:

Number of C stone (\$C + \$H) = C/H ratio

- (14) "Density."
- (15) "Melting Point."
- (16) "Freezing Polat."
- (17) "Boiling Point."
- (18) "Refractive Index."
- (19) "Vacuum Stability Test." (a)

A 5.0-gm sample (1.0 gm for initiators), after having been carefully dried is heated for 40 hours, in vacuo at the desired temperature.

- (20) "200 Graz Bomb Sand Test."
 - (a) Sand test for solids. (a)

A 0.4-gm sample of explosive, pressed at 3000 pounds per square inch into a No. 6 csp, is initiated by lead azide, or mercury fulminate (or, if necessary, by lead azide and tetryl), in a sand test bomb containing 200 gm of "on 30 mesh" Ottawa sand. The amount of azide, or of tetryl, that must be used, to insure that the sample trushes the maximum net weight of sand, is designated as its sensitivity to initiation and the net weight of sand crushed, finer than

30 mesh, is termed the sand test value. The net weight of sand crushed is obtained by subtracting from the total the amount crushed by the initiator when shot alone.

(b) Sand test for liquid. (b)

The sand test for liquids is mak in accordance with the procedure given for solids except that the following procedure for locating the test samples is substituted:

Cut the closed end from a No. 6 blasting cap and load one end of the resulting cylinder with 0.20 gm of lead axide and 0.25 gm of tetryl, using a pressure of 3000 psi for consolidating each charge. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8 or 9 inches long. Crimp to the pricked end a loaded cylinder, taking care that the end of the fuse is held firmly against the charge in the cap. Crimp near the mouth of the cap so as to svoid squeezing the charge. Transfer a veighed portion of 0.400 gm of the test emplosive to an aluminum cap, taking precautions when the emplosive is liquid to insert the assume in such a manner that as little as possible adheres to the side walls of the cap, and when a solid material is being tested use material fine enough to pass through a No. 100 U. S. Standard Sieve. The caps used shall be of the following dimensions: length 2.00 inches, internal diameter 0.248-inch, wall thickness 0.025-inch. Press solid emplosives, after insertion into the aluminum cap, by means of hand pressure to an apparent density of approximately 1.2 gm per cubic centimeter. This was done by exerting hand pressure on a wooden plunger until the plunger had entered the cap to a depth of 3.93 centimeters. Following are the dimensions of the interior of the cap; height 5.00 cm, area of cross section 0.312 square centimeters. Insert the cylinder containing the fuse and explosive charge of tetryl and lead axide into the aluminum cap containing the test explosive for the determination of sand crushed.

(21) "Sensitivity to Initiation."

This is sensitivity to initiation as described under the preceding heading. The minimum detonating charge, in gress, required to detonate the explosive sample, is given.

(22) "Ballistic Mortar, % TNT." (e)

The amount of sample wider test which is necessary to raise the heavy ballistic mortar to the same height to which it is raised by 10 gm of trinitrotoluene (TNT) is determined. The sample is then rated, on a proportionate basis, as having a certain TNT value, i.e., as being a certain percent as effective as TNT in this respect. The formula is

The ballistic mortar consists of a long compound supporting rod, at the end of which is supported a heavy short-need mortar. The mortar contains a chamber about 6 inches in diameter and 1 foot long. A projectile occupies about 7 inches of the chamber and the sample to be tested occupies a small portion of the remainder of the chamber. When the sample is detonated, the projectile is driven into a sand bank, and the mortar swings through an angle which is marked on paper by a pencil attached to the mortar. The angle thus indicates the height to which the pendulum is raised by the explosion, and this latter represents the energy measured by this test procedure.

(23) "Trauzl Test, % TMT." (d)

A sample of the explosive to be tested (of the order of 10 gm) is exploded in a cavity, or borehole, 25-mm in diameter and 125-mm deep, in a lead block 200-mm in diameter and 200-mm in height. The borehole is made centrally in the upper face of each block, which is east in a mold from desilverized lead of the best quality. Although these tests have been made under a variety

of conditions, where possible the data have been taken from or related to those of Reference f (Maoum). Here a No. 8 blasting cap was used for initiation of the sample contained in glass. The weight of sample used was adjusted to give, with the initiator, a total expansion of 250 to 300 cc, since within this range expansion and sample weight were linearly related under the conditions - Maourn's test. Thus expansions for equivalent weights were readily calculated, and the test alue expressed in percent of the expansion of an equivalent weight of TNT.

(24) "Plate Dent Test." (d)

Two methods were used for plate dent tests.

- (a) Method A Ine charge is contained in a copper tube, having an internal dismeter of 3/4-inch and 1/16-inch wall. This loaded tube is placed vertically on a square piece of cold-rolled steel plate, 5/8-inch thick; 4-inch and 3-1/4-inch square plate gave the same results. The steel plate is in a herizontal position and rests in turn on a short length of heavy steel tubing 1-1/2 inches ID and 3 inches OD. The charge rests on the center of the plate and the centers of the charge, plate, and supporting tube are in the same line. A 20-gm charge of the explosive under test is boostered by a 5-gm pellet of tetryl, in turn initiated by a No. 8 detonator.
- (b) Method B A 1-5/8-inch diameter, 5-inch long uncased charge is fired on a 1-3/4-inch thick, 5-square inch cold-rolled steel plate, with one or more similar plates is backing. The charge is initiated with a No. 8 detonator and two 1-5/8-inch diameter, 30-gm tetryl boosters.

Plate dent test value, or relative brisance = Sample Dent Depth x 100.

(25) "Prioration Rate." (g)

The detonation rates reported in the tables contained herein were determined principally by using the rotating drum camera, under the conditions stated, e.g., usually charges 1 inch in diameter, 20 inches long, wrapped in cellulose acetate sheet, and initiated by a system designed to produce high order stable detonation at the maximum rate under the particular conditions. A typical initiating system for this consisted of four tetryl pellets 0.995 inch in diameter, 0.75 inch long, pressed to 1.50 gm/cc, with a Corps of Engineers special blasting cap placed in a central hole in the end pellet.

b. Second tabular page.

(1) "Booster Sensitivity Test." (p)

The booster sensitivity test procedure is a scaled up modification of the Bruceton method (unconfined charge). The source of the shock consists of two tetryl pellets, each 1.57 inches diameter by 1.60 inches high, of approximately 100 gm total weight. The initial shock is degraded through wax spacers of cast Acrawax B, 1-5/8 inches diameter. The test charges are 1-5/8 inches diameter by 5 inches long. The value given is the thickness of wax in inches at the 50% detonation point. The weight of tetryl pellet noted is the minimum which will produce detonation with the spacer indicated.

(2) "Heat of" (calorimetric tests). (i)

Heats of combustion and explosion are generally determined on samples weighing of the order of 1 to 2 gm, in standard calorimeter bombs such as the Parr or Emerson, approximately 400 cc: (for low loading density), or the Boas, approximately 45 cc (for high loading density). For

heats of combustion the sample is burned under about 40 atmospheres of oxygen; for heats of explosion, nitrogen, or one atmosphere of air is used.

- (3) "Specific Heat."
- (4) "Burning Rate."
- (5) "Thermal Conductivity."
- (6) "Coefficient of Expansion."
- (7) "Hardness, Mohs' Scale."
- (8) "Young's Modulus."
- (9) "Compressive Starreth."
- (10) "Vapor Pressure."
- (11) "Decomposition Equation."
- (12) "Armor Plate Impact Test." (j)
 - (a) 60-mm Mortar Projectile.

A modified 60-mm, N49A2, mortar projectile is loaded with the explosive to be tested, drilled to the proper depth (about 1/2 inch), and a flat-based steel plug screwed into the projectile to give a smooth close-fit between the plug base and the charge. The part of the plug outside the projectile is rounded off in the form of a spherical section. The loaded projectile with fins attached is fired from a five foot length of 2-3/8 inches ID x 3-3/8 inches OD Shelby steel tubing. The igniter and propelling charge, consisting of an igniter for a 2.36-inch rocket (besonka), 5 gm of 4F bl.ck power, and a quantity of shotgun propellant sufficient to give the desired velocity (read from a calibration chart) are conveniently loaded into the "gun" through a simple breech plug. The velocities are measured electronically, and the reaction, inert or affected, is determined by observation (e.g., whether or not flash occurs on impact). Within the range of flight stability of the projectile, 200-1100 ft/sec, the 50% point is located.

- (b) 500-1b General Purpose Bombs.
- (13) "Bomb Drop Test."

Bomb drops are made using bombs assembled in the conventional manner, as for service usage, but containing oither inert or simulated fuzes. The target is usually reinforced concrete.

c. Third tabular page.

(1) "Fragmentation Test." (1)

The weight of each empty projectile and weight of water displaced by the explosive charge is determined, and from this the specific gravity of the charge is calculated. All 3-inch and 90-mm projectiles are initiated by M2O Booster pellets, and those used with 3-inch HE. M42Al, Lot KC-5 and 90-mm HE, M71, Lot WC-91 projectiles are controlled in weight and height as follows: 22.50 \pm 0.10 gm, and 0.480 to 0.485 inch.

AMCP 766-177

The projectile assembled with fure, actuated by a Hasting Cap, Special, Type II (Spec 19-20) placed directly on a lead of comparable diameter and booster, are placed in boxes constructed of half-inch pine. The 90-mm projectiles are fragmented in boxes 21 x 10-1/2 x 10-1/2 inches and the 3-inch projectiles in boxes 15 x 9 x 9 inches outside diamesions. The box with projectile is placed on about 4 feet of sand in a seel fragmentation tub, the detorator wires are connected, and the box covered with approximately 4 feet more of sand. The projectile is fired and the sand run onto a gyrating 4-mesh screen on which the fragments are recovered.

(2) "Fregment Velocity."

Charges 10-1/8 inches long and 2 inches in diameter, containing a booster cavity, filled by a 72-gm tetryl pellet (1-3/8 inches diameter, 2 inches long, average density 1.594) are fired in a model projectile of Shelby seamless tubing, 2 inches ID, 3 inches OD, SAE 1020 steel, with a welded-on cold rolled steel base. The projectile is so fired in a chamber, connected to a corridor containing velocity stations, that a desired wedge of projectile casing fragments can be observed. The fragment velocities are determined by shadow photographs, using flash bulbs, and rotating drum cameras, each behind three slits. The drum cameras have a writing speed of 30 meters per second.

(3) "Blast (Relative to TNT)."

The blast pressures and impulses given were determined almost exclusively with tourseline gages, and the usual necessary specialized electrical circuits, shielded cc-axial cables, oscillographs, etc. In general, the data represent results of tests with large cased charges.

(4) "Shaped Charge Effectiveness, TRT = 100." (k, m)

Unconfined charges 2 inches in diameter and 5 inches long, boostered by a 10-gm pressed tetryl pellet, set in a 20-mm pellet (truncated come) of cast 60/40 cyclotol, are shot against 3-inch homogeneous armor plate at a 1-3/16 inches standoff. The comes used are commercial Pyrenglass funnels, sealed off at the start of the stem, 2 inches in diameter, 0.110 to 0.125 inch well thickness.

Unconfined charges 1.63 inches in dismeter and 6 inches long are tested at a standoff of 1.63 inches against stacks of $4 \times 4 \times 1$ inch mild steel plates. M9Al steel cones are used. Results are averages of 4 trials.

- (5) "Color."
- (6) "Principal Uses."
- (7) "Method of Loading."
- (8) "Loading Density."
- (9) "Storage."

Ammunition and bulk emplosives in storage represent varying degrees of hazard and compatibility. This has led to their being divided into a number of hazard classes and compatibility groups as indicated in subparagraphs (b) and (c) below.

- (a) Mathod: Wet or dry.
- (b) Hazard Class (Quantity-Distance).

Assumition and bulk explosives are divided into quantity-distance classes, Class 1 through 12, according to the damage expected if they explode or ignite (Reference: Army Material Command Regulation, ANCR 385-100, ANC Safety Namual, chapter 17). All standard explosives in bulk are included in four of these classes: Class 2, 2A, 9, and 12 (TM 9-1910/TO 11A-1-34).

(c) Corpatibility Group.

Explosives and assumition are grouped for compatibility with respect to the following factors:

- 1. Effects of explosion of the item.
- 2. Rate of deterioration.
- 3. Sensitivity to initiation.
- 4. Type of packing.
- 5. Effects of fire involving the item.
- 6. Quantity of explosive per unit.
- (d) Emdation.

d. Miscellaneous entries.

Where available and appropriate, the following or related data are given, in space at the bottom of the third form, or on plain pages.

- (1) Solubility.
- (2) Methods of manufacture.
- (3) Historical information.
- (4) Bulk compressibility modulus. (q)

The direct experimental measurement of the dynamic bulk modulus of a solid is difficult, and few such measurements have been made. One apparatus has been developed at the mayal Ordnance Laboratory and is described in detail in Reference q. Bulk modulus (its reciprocal is the compressibility) is defined as the ratio of stress to strain when the stress is a pressure applied equally on all surfaces of the sample and the strain is the resulting change in volume per unit volume.

· (5) Hydrolysis tests. (o)

The 240-hour hydrolysis test is conducted as follows: A 5-gm sample of the dry nitrocellulose is weighed accurately in a tare-weighed 250-oc Pyrex flask having a ground glass connection for a Pyrex condenser. Then 100 cc of distilled water is added to the nitrocellulose in the flask and the flask fitted to the condenser. The flask is placed in a steam bath in which the water is kept boiling constantly by means of electric hotplates. At the end of 240 hours the amount of solid developed by the hydrolysis of the nitrocellulose is measured by an electromatic pH method.

(6) Sensitivity to initiation by electrostatic discharge. (n)

The samples are tested under two amounts of confinement, designated as unconfined and confined. In the unconfined test, a sample of approximately 0.05 gm is dumped into a shallow depression in a steel block and flattened out with a spatula. In the confined tests (partly confined), the sample of approximately 0.05 gm is introduced into soft-glass tube (~7 mm ID x 18 mm long) which fits over a metal pag. The volume of the space around the charge at zero gap is ~0.15 cc; at a gap of 0.6 mm; it is ~0.4 cc. In addition to providing moderate confinement, this system also minimizes dispersion of the sample by the test spark, and reduces the effect of material being repelled from the needle point by electrostatic field effect.

When a test is to be made, the needle point electrode is screwed up until the gap between electrodes is greater than the critical gap discharge at the test voltage. The sample is then placed in position, the high-voltage terminal of the charged condensor is switched to the point electrode by means of a mercury switch, and the electrode is screwed down until discharge occurs.

The spark energy (in joules), for zero probability of ignition, is determined.

(7) Destruction by chemical decomposition.

Burning is the preferred method of destroying explosives. Initiating type explosives (in quantity) are usually destroyed by detourtion with demolition blocks. Destruction of explosives by chemical decomposition can be effectively used where small laboratory quantities are involved. Procedures given are standard for only lead axide, mercury fulminate and nitroglycerin.

- (8) Other information.
- (9) Ruferences.

6. REFERENCES CITED IN INTRODUCTION. 1

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- b. W. R. Tomlinson, Jr. and A. J. Clear, Development of Standard Tests -- Application of the Impact and Sand Tests to the Study of Mitroglycerin and Other Liquid Explosives, PATR No. 1738, 13 June 1949.
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- g. G. J. Mueller, Equipment for the Study of the Detonation Process, PATR No. 1465, 4 July 1945.
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Por information regarding source of references, inquiries should be made to the Commander, U.S. Army Research Office--Durham, ATTN: CRDARD-EH, Box CM, Duke Station, Durham, North Carolina 27706.

- k. Batern Labouatory, du Pont, Investigation of Cavity Effect, Section III, Variation of Cavity Effect with Composition, NIRC Contract W-672-ORD-5723.
 - 1. J. H. McIvor, Fragmentation Test Procedures, PA Testing Manual 5-1, 24 August 1950.
- m. Bastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, 18 September 1943, MIRC Contract V-572-ORD-5723.
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- o. D. D. Sager, Study of Acid Adsorption and Hydrolysis of Callulose Mitwate and Callulose Sulphate, PATR No. 174, 12 January 1932.
- p. L. C. Smith and R. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, GRD Report No. 5746, 27 December 1945.
- q. C. S. Sancler, An Acoustic Technique for Measuring the Effective Dynamic Bulk Mcdulus of Elasticity and Associated Loss Factor of Rubber and Plastics, MAVORD Report Sc. 1524, 1 September 1950.
- W. S. Cramer, Bulk Compressibility Data on Severel Explosives, MAVORD Report No. 4380, 15 September 1956.

Amatol, 80/20

| Oxygen Belence: CO: % +1 CO: % +1 Pensity: gm/cc Cast 1.46 Melting Point: "C | |
|--|---|
| Density: gm/cc Cast 1.46 Molting Point: "C | |
| Melting Point: 'C | |
| | |
| Provides Balaty IC | |
| Freezing Point: *C | |
| Belling Point: *C | |
| 1 | |
| n2 n2 | |
| Vecuum Stability Test: | |
| cc/40 Hrs, at | |
| | |
| | |
| | |
| 150°C 6.8 | |
| | |
| Sand, gm 35.5 | |
| Sensitivity to Initiation: | |
| | |
| 1 | |
| | |
| | |
| | |
| Trend Test, % TNT: (b) 123 | |
| Place Bent Test: Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |
| Detenation Rate: Confinement None None | |
| Condition Cast Cast | |
| Charge Diameter, In. 1.0 1.0 Density, gm/cc 1.46 1.50 | |
| | |
| | Refrestive Index, no. |

C

Amatol, 80/20

| agmentation Toot: | Shaped Charge Effectiveness, TNT = 100: |
|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Canes |
| Dunsity, gm/cc | Hole Volume |
| Charge Wt, Ib | Hole Dopth |
| Total No. of Fragments: | Celer: Buff-yellow |
| For TINT | Color: Buff-yellow |
| For Subject HE | Principal Uses: Bombs, RE projectiles |
| 3 inch HE, MGZAT Projectile, Let KC-5: | Things our Buss, is projectizes |
| Density, gm/cc | |
| Churge Wit, Ib | |
| Total No. of Fragments: | Method of Londino: Cast |
| For TINT | Method of Looding: Chart |
| For Subject HE | |
| | Leeding Density: gm/cc 1.46 |
| gment Velocity: ft/sec (f) At 9 ft 1900 | |
| At 9 ft 1900 At 25 1/ ₂ ft 1750 | Storege: |
| Density, gm/cc | |
| • | Method Dry |
| nt (Relative to TNT): | Hazard Class (Quantity-Distance) CLass 9 |
| Alex | Compatibility Group Group I |
| Pecik Pressure | |
| Impulse | Exudation Does not exude at 65°C |
| Energy | |
| Air, Cantined: | Booster Sensitivity Test: (a) |
| Impulse | Condition Pressed |
| | Tetryl, gm 100 |
| Under Weter: Pack Pressure | Wax, in. for 50% Detonation 0.83 |
| Impulse | Density, gm/cc 1.65 |
| Energy | Heat of: (d, e) |
| Undergrounds | Combustion, cal/gm 1002* |
| Peck Pressure | Explosion, cal/gu 490* Gas Volume, cc/gm 930* |
| Impulse | Gas Volume, cc/gm 930* |
| Energy | |
| | |
| | |
| | |

Amatol, 60/40

| Competition: | | Melecular Weight: | 100 |
|--|----------|---|------|
| | | Oxygen Bolonce: | - |
| Ammonium Nitrate | 50 40 | CO ₂ % | -18 |
| 181 | 40 | CO % | + 2 |
| | | Density: gm/cc Cast | 1.60 |
| | | Melting Point: *C | |
| C/H Ratio | | Freezing Point: "C | · |
| Impact Sensitivity, 2 Kg Wt: Burrou of Mines Apparatus, cm | 95 | Bailing Point: *C | |
| Sample Wt 20 mg | 92 | Refractive Index, no | |
| Picatinny Arsenal Apparatus, in. | 16 | ng. | |
| Sample Wt, mg | 17 | - | |
| | | n ₂₀ | · |
| Friction Pandulum Test: | | Vocuum Stability Test: | |
| Steel Shoe | | cc/40 Hrs, at | |
| Fiber Shoe | | 90°C | |
| Riffe Suffet Impact Test: Trials | | 100°C | |
| % | | 120°C | |
| Explosions | | 135°C | • |
| Partials | | 150°C | |
| Burned | | 200 Grem Bomb Sond Test: | |
| Unaffected | | Sand, gm | 41.5 |
| Explosion Temporature: "C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 Decomposes 270 | | Lead Azide | 0.20 |
| 10 | | Tetryl | 0.06 |
| 15 | | B.M. A. | 128 |
| 20 | | Ballistic Morter, % TNT: (a) | 120 |
| 75°C International Heat Test: | | Trousi Test, % TNT: | |
| % Loss in 48 Hrs | | Plate Deat Test: Method | |
| 100°C Heat Test: | | Condition | |
| % Loss, 1st 48 Hrs | | Confined | |
| % Loss, 2nd 48 Hrs | | Density, gm/cc | |
| Explosion in 100 Hrs | | Brisance, % TNT | |
| Flommobility ludex: | | Detenation Rate: | |
| the state of the s | | Confinemen | Yone |
| Hygreecepicity: % | | Condition | Cast |
| ···/g-cacopicay: 70 | | Charge Diameter, in. | 1.0 |
| Velotility: | Nil | Density, gm/cc | 1.50 |
| · | 1417 | Rate, meters/second | 5760 |

| Fregmentation Test: | | Shaped Charge Effectiveness, TNT = 100: |
|---|---------------------------------------|--|
| 90 mm HE, M71 Projectile, Let \ | WC-91: | Glass Cones Steel Cones |
| Density, gm/cc | 1.49 | Hole Volume |
| Charge Wt, Ib | 1.971 | Hole Depth |
| Total No. of Fragments: | | |
| For TNT | 703 | Color: Buff-yellow |
| For Subject HE | 583 | District House and the second |
| 3 inch HE, M42A1 Projectile, Let | KC-5: | Principel Uses: Bombs, HE projectiles |
| Density, gm/cc | 1.57 | |
| Charge Wt, Ib | 0.827 | |
| Total No. of Frequents: | | Marked of London |
| For TNT | 514 | Method of Leading: Cast |
| For Subject HE | 408 | |
| | | Leeding Density: gm/cc 160 |
| Fragment Velocity: ft/sec At 9 ft At 251/4 ft | | Storoge: |
| Density, gm/cc | | |
| | | Method Dry |
| lius! (Relative to TNT): | · · · · · · · · · · · · · · · · · · · | Hazard Class (Quantity-Distance) Class 9 |
| Ain | | Compatibility Group Group I |
| Peak Pressure | 95 | 7 |
| Impulse | 85 | Exucation Does not exude at 65°C |
| Energy | 84 | |
| Air, Confined: | | Heat of: (d, e) |
| Impulse | | Combustion, cal/gm 1658* |
| <u> </u> | | Explosion, cal/gm 633* |
| Under Weter: | | Gar Volume, cc/gm 380* |
| Peak Pressure | | |
| Impulse | | |
| Energy | | |
| Underground: | | |
| Peak Pressure | | |
| Impulse | | ` \ |
| Energy | | |
| | | |
| | | : |
| | | |
| | | MODI muladad dan ang atau |
| | | *Calculated from composition of mixture. |

Amatol, 50/50

| Compositions | Melecular Weight: | | 118 |
|--|----------------------------|----------|------|
| ₩ | Guygen Balance: | | |
| Ammonium Riffate 50 | CO, % | | 27 |
| THT 56 | CO % | | - 3 |
| | Density: gm/cc () | est | 1.50 |
| | Melting Point: *C | | ? |
| C/H Retio | Freezing Point: *C | | |
| Impact Sandbirley, 2 Kg Wt: | Solling Point: *C | | |
| Bureau of Mines Apparatus, cn: 95 Semple Wt 20 mg | Refractive Index, no | | |
| Picatinny Arsenal Apparatus, in. 16 | | | |
| Sample Wt, mg | nº | | |
| | n <u>n</u> | | |
| Folation Fendulum Test: | Vocuum Stubility Test: | | |
| Steel Shoe Uneffected | cc/40 Hrs, at | | |
| Fiber Shoe Unessected | 90°C | | |
| Rillo Bullet Impact Yest: Trials | 100°C | ٠ | :0.2 |
| % | 120°C | | 1.0 |
| Explosions 0 | 135°C | | |
| Portiols 0 | 150°C | | |
| Burned 0 | 200 Gram Bomb Sand Toor: | | |
| Unaffected 100 | Sand, gm | | 42.5 |
| Explacion Temperature: 'C | Sensitivity to Initiation: | | |
| Seconds, 0.1 (no ccp used) | Minimum Detonating Ch | orge, gm | |
| 1 2 | Mercury Fulminate | | |
| 5 Decompos as 265 | Lead Azide | | 0.20 |
| 10 | Tetryl | | 0.05 |
| 15 20 | Balliotic Mortor, % TNT: | (e) | 124 |
| | Trough Test, % THT: | | |
| 75°C International Most Test: % Lass in 48 Hrs | Plate Dent Test: | | _ |
| | Method | | В |
| 180°C Heat Test: | Condition | | Cast |
| % Loss, 1st 48 Hrs | Confined | | No |
| 96 coss, 2nd 48 Hrs | Density, gm/cc | | 1.55 |
| Explosion in 100 Hrs | Brisance, % TNT | | 52 |
| Floranshillty Index: | - Detenation Rate: | | _ |
| Fuciamentally States: | Confinement | None | None |
| Hygreecopicity: % N11 | Condition | Cost | Cast |
| mygracepany: 70 | Charge Diameter, in. | 1.0 | 1.0 |
| Volatility: | Density, gm/cc | 1.55 | 1.55 |
| - american | Rate, meters/second | 6430 | 6230 |

Amatol, 50/50

| regressionien Test: | | Shaped Charge Effectiveness, TNT = 100: | |
|------------------------------------|----------|---|--------------------------|
| 90 mm KE, M71 Projectile, Le | t WC-91; | Glass Cones Steel Cones | (g) |
| Density, gm/cc | 1.55 | Hole Volume 53 | |
| Charge Wt, Ib | 2.053 | Hole Depth 69 | . - |
| Total No. of Fragments: | | | |
| For TNT | 703 | Color: Buff-ye)low | |
| For Subject HE | 630 | | |
| 3 Inch HE, MASA1 Projectile, L | a KCS: | Principal Vess: Bombs, HE projectiles | * |
| Density, gm/cc | 1.54 | ì | <i>;</i> |
| Charge Wi, ib | 0.819 | | |
| Total No. of Fragments: | • | | , |
| For TNT | 514 | Method of Looding: Cast | |
| For Subject HE | 385 | | |
| | | Leading Bessity: gm/cc 1-59 | |
| agment Velesity: ft/sec At 9 ft | | | |
| At 251/4 ft | | Sturnge: | |
| Density, gm/cc | | Method Dry | (|
| est (Relative to TNT): | · | Hozord Class (Quantity-Distance) Class 9 |) |
| Ain | | Compatibility Group Group I | : |
| Peak Pressure | 91 | | |
| Impulse | 87 | Exudation Does not exude at 65°C | |
| Energy | | ` ` | |
| Al- C-C-4 | | Booster Sensitivity Test: (a | |
| Alr, Confined: Impulse | | | ist 10. |
| | | | 60 |
| Under Weter: | 4 | Density, gm/ce | |
| Peak Pressure | | Heat of: | l. e) |
| Impulse | | Combustion, cal/gm 19 | |
| Energy | 93 | | 103 * 155* |
| Underground: | | *Calculated from composition of mixtu | re. |
| Peak Pressure | 104 | Specific Heat: cel/gm/°C (i) | |
| Impulse | 104 | Temp, 20° to 80°C 0. | 363 |
| Energy | 104 | Bomb Drop Test: T7, 2000-1b Semi-Armor-Piercing Bomb vs Concrete: | |
| | | Hax Safe Drop, ft. 4000- | 5000 |

Compatibility with Merals:

May - Metals unaffected are sinc, iron, tin, braus, brass tin plated, brass RRC coated, brass shellac coated, nickel aluminum, steel, steel plated bith nickel, sinc or tin, stainless steel, Parkerized steel, and steel coated with acid-proof black paint. Metals slightly affected are copper, bronze, lead and copper plated steel.

Preparation:

In preparing amatols the proper granulation of amonium nitrate is required if the eximum density of the cost amatol is desired. The ammonium nitrate should be dried so as to contain not more than 0.25% moisture. It should be heated to about 90°C before being added to the appropriate weight of molten TNT contained in a melting vessel equipped with an agitator. Contained in the shall or bombs.

Origin:

Developed by the British during world War I in order to conserve TNT.

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- (a) L. C. Smith and B. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSED Report 5746, 27 December 1945.
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- L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRV Report No. 5746, 27 December 1945.
- (3) Committee of Div 2 and 8, HDRC, Report on HBX and Tritonal, OSRB Report No. 5406, 31 July 1945.
- (e) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, MAVORD Report No. 87-46, 26 July 1946.
- (f) R. W. Drake, <u>Pragment Velocity</u> and Panel Penetration of Several Explosives in Simulated <u>Shells</u>, OSRD Report No. 5622, 2 January 1946.
- (g) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Final Report, 18 September 1943, NDRC Converet W-672-ORD-5723.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Amatols:

| <u>o</u> | 1 | 2 | 3 | <u>4</u> | <u> 2</u> | <u>6</u> | 7 | 8 | 2 |
|--|---|--|---|----------------------------------|--|--|--------------------------------------|--|---|
| 240 350 630 950 1300 1530 | 681 731 901 1051 1311 1451 1651 | 132 182 1302 1352 1372 1552 | 743 1173 1373 1323 1493 1763 | 364 694 734 874 1344 | 65 425 695 715 735 1145 1245 1345 1455 1885 | 266 556 666 986 1376 1446 1636 1796 | 1207 1457 17-7 1827 2167 | 54-8 638 838 1098 1148 1388 1568 1838 | 549 799 929 1129 1219 1369 1559 |

(i) TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

²See footnate 1, page 10.

Amages]

| Composition | Makingthe Weight: 102 |
|--|---|
| Amonium Nitrate 22 SRI 67 Aluminum 11 | Oxygen Balence: CO, % CO % -22 |
| | Daniel gm/cc Cest 1.65 |
| | Melting Politic C |
| C/H Ratio | Property Points C |
| Im act Venility by, 2 Kg WI: | Boiling Peint: C |
| Bureau of Mines Apparatus, cm 91 Same e W 20 mg Picatinny Arsenal Apparatus, in. 11 Semple Wt, mg 19 | Refroetive Index, no. no. no. |
| Fri-tion Pandurum Tast: Start Shoe Fiber Shoe | Version Stability Tea: cc/40 Hrs, at 90°C |
| Rifle Bullet (sepect Test: Trials 96 Explosions Partials | 120°C 4.4.4.150°C |
| Burnod Unaffected | 300 Grem Ramb Sand Test: Sand, gm h7.8 |
| Explosion Temperature: *C Seconds, 0.1 (no cap used) 1 5 Decomposes 265 | Sensitivity to Initiation: Minimum Detonating Charge, grn Mercury Fulminate Lead Azide Tetryl |
| 15 20 | Ballistic Morter, % TNT: (a) 122 |
| | Treuxi Test, % TNT: |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Tesi: Method |
| 100°C Hoot Toot: | Condition Contined |
| % Loss, 1st 48 Hrs 0.00 | Density, gm/cc |
| % Loss, 2nd 48 Hrs 0-10 Explosion in 100 Hrs None | Brisance, % TNT |
| Flammebility Index: | Detenution Rete: Confinement |
| Hygrescapicity: % | Condition Charge Diameter, in. |
| | Density, gm/cc |

Ammona 1

| Progmontation Test: | | Shaped Cherge Effectiveness, TNT == 100: |
|--|--|---|
| 90 mm HE, M71 Projectile, Let V | VC-91: | Gloss Cones Steel Cones |
| Density, gm/cc | | Hole Volume |
| Charge Wt, to | | Hole Depth |
| Total No. of Fragments: | | |
| For TNT | | Colors |
| For Subject HE | | Dischart these Protection (NY) |
| 3 inch HE, M42A1 Projectile, Lut | KC-5: | Principal Uses: Projectile filler |
| Density, gm/sc | 1.65 | |
| Charge Wt, Ib | | |
| Total No. of Fragments: | | Marked of headhan |
| For TINT | 655 | Method of Leading: Cast |
| For Subject HE | 550 | Leeding Density: gm/cc 1.65 |
| Fragment Valority: ft/sec | | 1.85 |
| At 9 ft At 25½ ft | | Storage: |
| Density, gm/cc | - | |
| | | Method Dry |
| Bleet (Religitive to TNT): | | Hazord Class (Quantity-Distance) Class 9 |
| Ain | | Compatibility Group |
| Peak Pressure | | Frankskan |
| Impulse | | Exaderion |
| Energy | | |
| Ale, Confined: | | Origin: |
| impulse | | Castable mixture developed in United State during World War I. |
| Under Weter: | | |
| Peak Pressure | | References: |
| Impulse Samuel | | (a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, |
| En igy | | PATR No. 1372, 29 November 1943. |
| Underground: | | (b) Also see the following Picetinny Ar- |
| Peak Presture | * | senal Technical Reports on Ammonals: 1108, |
| Impulse Second | | 1286, 1292, 1308 and 1783. |
| Energy | | |
| Preparation: | | |
| Procedure same as describe except aluminum is added to trate-INT molten mixture und til uniformity in compositional in accomplished by processing is accomplished by the complished by the complex c | the ammonium ni- der sgitation un- on is obtained. | |

Armonium Mitrate

| Composition: | | | Meisenter Weight: (B _i X | 203) | 80 |
|---|------------------|------------------|---|----------------------|---------------------------------------|
| H 35 | , | : | Oxygen Belense: CO: % CO % | | +20 +20 |
| H 5 | • | MB, MO | Benelty: gm/cc Crysts | 1 | 1.73 |
| 0 60 | | | Making Point: °C | | 170 |
| C/H Ratio | | | Freezing Point: *C | | |
| Impact Sensitivity, 2 Kg W | | | Boiling Point: *C | | · · · · · · · · · · · · · · · · · · · |
| Bureau of Mines Apparo Sample Wt 20 mg Picatinny Arsenal Appar Sample Wt, mg | | 100+ 31 17 | Refrestive index, ng ng ng | | |
| Printies Pendelum Test: Steel Shoe Fiber Shoe | Unaff Unaff | | Vecum Stability Test: cc/40 Hrs, at 90°C | | |
| RMo Bullet Impact Test: | Trials | | 100°C | | 0.3 0.3 |
| P bankan | % | | 135°C | • | |
| Explosions Partials | 0 | | 150°C | | 0.3 |
| Burned Unaffected | 0 | | 200 Graw Bemb Sand Text: Sand, gm | , | E1 |
| Explosion Temperature: Seconds, 0.1 (no cop us 1 5 Ignites 10 | •C ed) 465 | | Sensitivity to Initiation: Minimum Detonating Ch Mercury Fulminate Lead Azide Tetryl | oarge, gm | 0-20 0-25 |
| 15 | | | Sallistic Morter, % TNT: | (a) | 56 |
| 20 | | | Trougi Test, % TNT: | \ - / | |
| 75°C International Heat To % Loss in 48 Hrs | st: (a) | 0.0 | Plate Dent Test: Method | | |
| 100°C Heat Test: | | | . Condition | | |
| % Loss, 1st 48 Hrs | | 0.74 | Confined | | |
| % Loss, 2nd 48 Hrs | | 0.13 | Density, gm/cc | | |
| Explosion in 100 Hrs | | None | Brisance, % TNT | | |
| | | | Condition | (b) None Solid | Strong Liquid |
| Flammability Index: | | | | | 1.700170 |
| Hygrecopicity: % 30°C, 90% RH | | Extreme | Charge Diameter, in. Density, gm/cc | 1.25 | 4.5 1.4 |

Ammonium Mitrate

| Secretar Semplifyity Tests | Decomposition Squatten: (f) Chygen, otoma/sec 1013.8 (h) 1012.3 |
|--|---|
| Condition | Crygen, etems/sec 10 ^{13.0} 10 ^{12.3} |
| Tetryl, gm. | Heat, kilocolorie/mole 40-5 38-3 |
| West, In. for 50% Detanation | (AH, kcol/mol) |
| Wax, gm | Temperature Range, *C 243-261 217-267 |
| Density, gm/cc | Phase Idenia |
| Heat of: | Armor Plate Impact Test: |
| Combustion, cal/gm 346 | |
| Explasion, cel/gm 346 | 60 mm Morter Projectile: |
| Gas Volume, cc/gm 980 | 50% Inert, Velocity, ft/sec |
| Formation, col/gm 1098 | Aluminum Fineness |
| Fusion, cal/gm 18.23 | SOO-Ib General Purpose Bombe: |
| Specific Heat: col/gm/°C (e) | , |
| o _C o _C | Plate Thickness, inches |
| -150 0.189 0 0.397 -100 0.330 50 0.412 | |
| -100 0.330 50 0.41% -50 0.364 100 0.426 | 114 |
| 200 01.125 | 11/4 |
| | 192 |
| Burning Rate: | |
| cm/sec | Semi- Dres Test: |
| | same oray tar: |
| Thermal Conductivity: col/sec/cm/°C 2.9-3.9 x 10 ⁻⁴ | T7, 2006-16 Semi-Armor-Plorcing Somb vs Concrete: |
| Coefficient of Expension: | Max Safe Drop, ft |
| Linear, %/°C | 500-lb General Purpose Bomb vs Cuscrete: |
| Volume, %/°C | Height, ft |
| | Trials |
| Hordness, Mohe' Scale: | Unaffected |
| Maria Alai Alai Alai | Low Order |
| Young's Modulus: | High Order |
| E', dynes/cm² | |
| E, lb/inch² | 1060-lb General Purpose Bomb v. Concrete: |
| Density, gm/cc | Height, ft |
| Compressive Strength: Ib/inch² | Trials |
| acting to the state of the stat | Unaffected |
| Y 1 | Low Order |
| Vapor Pressure: (g) *C mm Mercury | High Order |
| 188 3.25 | Congression and Section 2 |
| 205 7.45 | |
| 21 6 11.55 | |
| 223 15.80 236 21:8 | |

Ammonium Mitrate

| Prognontation Test: | Shaped Charge Effectivelets, TNT == 100: | | | | | |
|---|--|--|--|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hale Valume Hale Depth | | | | | |
| Total No. of Fragments: For TNT | Color: Colorles» | | | | | |
| For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: Explosive ingredient of mixtures used in bombs or large caliber projectiles | | | | | |
| Total No. of Fragments: For TNT For Subject HE | Mushed of Leeding: Pressed or cast depending on composition of mixture | | | | | |
| Fregment Velocity: ft/sec At 9 ft At 251/s ft Density, gm/cc | Storage: Method Dry | | | | | |
| Blast (Relative to TNT): | Hazard Class (Quantity-Distance) CLASS 12 | | | | | |
| Air: Peak Pressure Impulse Energy | Compatibility Group Group D Exudation Name | | | | | |
| Air, Confined: Impulse | Effect of Temperature on Impact Sensitivity (Chemically pure grade): (b) | | | | | |
| Under Water: Peak Pressure Impulse Energy Underground: | Temp. PA Impact Test OC 2 Kg Wt, inches 25 31 75 28 100 27 150 27 175 12 | | | | | |
| Peak Pressure Impulse Energy | Compatibility with Metals: (a) In the presence of moisture, ammonium nitrate reacts with copper, iron steel, brass, lead and cadmium. | | | | | |
| | Entropy: (g) | | | | | |
| | cal/mol at 25°C 36.0 | | | | | |

Ammonium Mitrate

Solubility of emcaium nitrate, grame in 100 grams (\$) of: (e)

| <u> 14</u> | ter | Alo | opoj | Acet | lc Acid | | Mitric | Acid | Py | ridine |
|------------|--|----------------------------|-------------------------|--|-----------------------------------|---------------------------|-----------------------------|--------------------------------------|---------|--------|
| 888889 | 118 198 198 1997 421 580 871 | °C 20 40 60 78 | 2.5 5 7.5 10.5 | °C 16.6 27.0 80.9 101.0 120.0 | 5.0 0.39 5.8 20.7 125 | °c 0 15 30 75 | \$5.1 73.0 106 201 | Acid 30.0 21.7 20.8 31.6 | °ু হ | ~জন্জ |

Preparation:

Ammonium nitrate is prepared by the neutralization of an aqueous solution of ammonia with nitric acid and evaporation of the solution. The product which is very pure is dried in a graining kettle.

Origin:

First prepared by Glauber in 1659 and first used as an explosive ingredient in 1867 when a Swedish patent was granted to Chlason and Morrbin for a composite dynamite.

Destruction by Chemical Decomposition:

Associum nitrate is decomposed by strong alkalies with the liberation of associa, and by sulfuric acid with the formation of associum sulfate and nitric acid.

References:

- (a) Departments of the Army and the Air Force TM 9-1910/TO 11a-1-34, Military Emplosives, April 1955.
- (b) P. F. Macy, T. D. Dudderar, E. F. Reese and L. H. Eriksen, Investigation of Sensitivity of Fertilizer Grade Associus Mitrate to Explosion, PATR No. 1658, 11 July 1947.
 - (c) D. P. MccDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (e) International Critical Tables, McGraw-Hill Book Co., N. Y., Land-Bornst.
- G. D. Clift and B. T. Federoff, A Manual for Explosives Laboratories, Vol. II, Lefax Society, Inc., Philadelphia, 1943.
- (f) R. J. Pinkelstein and G. Gamow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
- (g) George Peick, The Dissociation Pressure and Free Energy of Formation of Ammonium Mitrate, Arthur D. Little, Inc., J Am Chem Soc, 76, 5858-60 (1954).
- (h) M. A. Cook and M. Taylor Abegg, Isothermal Decomposition of Explosives, University of Utah, Ind Eng Chem, June 1956, pp. 1090 to 1095.

³See footnote 1, page 10

perconium Mitrate

AMCP 706-177

| (1) | WITEO MEG | cale zorrow | Tif Lione | TIM VINE | met facilit | TOST Wabo | 138 OH FA | monton 47 | W # 0# ! |
|----------------------------|---------------------|-------------|-----------------------------|--|---|--|-----------------------------|-----------------------------------|-----------------------------|
| , Q. | 1 | 2 | 3 | , 4 | 2 | <u>6</u> | I | 8 | 2 |
| 250 630 1290 1720 | 731 1351 1241 | | 743 1323 1763 2183 | 364 984 1094 1214 1234 1304 | 695 1145 1225 1455 1635 1675 1725 | 596 666 676 946 1106 1696 | 907 1117 1947 2167 | 548 638 938 1008 1038 | 799 1 369 1409 |

Ammonium Perchlorate

| Compention: | Melecular Weight: (CLELNO) | 117.5 |
|---|--|--|
| % 0.8 11.9 | Oxygen Belease: CO ₂ % CO % | +27.3 +27.3 |
| ME, CLO, | Dunelty: gm/cc | 1.95 |
| 3.4 | Malting Point: *C | |
| 0 54.5 C/H Ratio | Principle Telent: °C | |
| Impact Spelitity, 2 Kg Wt: | Beiling Points *C | |
| Sample Wt 20 mg Picetinm, Areenal Apparatus, in. 24 Sample Wt, mg. 24 | Refrective Index, no. | |
| Frieties Fundulum Test: | Vuccinum Stebility Test: | |
| Steel Shoc Bnaps Fiber Shoe Uncerted | cc/40 Hrs, at 90°C | |
| Riffe Bellet Empect Tests Trials | 100°C | 0.13 0.20 |
| % | 135°C | |
| Explosions Portiols | 150°C | 0.32 |
| Burned Unaffected | 290 Grem Bomb Sand Yest: Sand, gre | 6.0 |
| Explosion Temperature: "C | Secultivity to Initiation: | and the second s |
| Seconds, 0.1 (no cop used) | Minimum Detonating Charge, gm | , \$ t - 1 |
| 1 5 435 | Morcury Fulminate | , |
| 10 | Lead Axide Tetryl | 0.20 0.25 |
| 15 | | U-2) |
| 20 () () () () () () () () () (| Ballistic Mortor, & TMT: | |
| | Toward Tost, % TN": | |
| 75°C International Heat Text; % Loss in 48 Hrs | Plate Dent Test: Mathed | |
| 160°C Heet Yest: | Condition | |
| % Loss, 1st 48 Hrs 0.02 | Confined | e e e e e e e e e e e e e e e e e e e |
| % Locs, 2nd 48 Hrs 0.00 | Density, gm/cc | |
| Suplosion in 100 Hrs Rone | Brisance, % TNT | |
| Flammability Index: | Detanation Rate: Confinement | |
| Hygrescopicity: % | Condition Charge Diameter, in. | |
| | Density, gm/cc | |

Assonium Perchlorate

| V 6000 | |
|--|--|
| Progmostatica Tests | Shoped Charge Effectiveness, THT = 190: |
| 90 mis Mt, M71 Fregratte, Lat WC-91: | Gloss Cones Steel Cores |
| Cancilly, gen/cc | Hole Volume |
| Constitution of the second | Hole Depth |
| | |
| Tabai bin. / Journales | |
| For TNT | Gebet Colorless |
| For Subject HE | |
| | Principal Usus: Explosive ingredient of |
| 3 hab Pts, MIZAT Projection, Let MC-3: | mixtures used in pyrotochnics and |
| Jenetty, gan/a | as projectile filler |
| Charge Wt. St. | |
| | |
| Total No. of Programatic | Method of Leading: Pressed or cast depending |
| INT INT | on composition of mixture |
| For Subject ISE | |
| | Leeding Density: gm/cc Variable |
| Programma Velically: ft/sec. | |
| À9A | |
| Ar 25% ft | Steregit 1 |
| Density, grn/cc | |
| | Methos Dry |
| Blant (Exhative to TNT): | Hazard Class (Quantity-Distance) Class 9 |
| | Tractic diagrams, 2 Marion, 2 Marion |
| | Compatibility Group |
| Peak Pressure | |
| Impulse | Exudatic None |
| Energy | |
| | Solubility in Water |
| Ale, Graffinger | gm/200 cc saturated solution; |
| Impulse | |
| Value Weter: | 2)°C 20 |
| Peak Prosume | 60°C 39 |
| Impulse | 100°C 88 |
| Energy | Present stand |
| | Prepasition: |
| Undergreand: | The perchlorates are prepared by the action |
| Peak Pressure | of the acid on a suitable base; by the ther- |
| Impulse | mal decomposition of certain chlorates; and by the electrolysis of chlorates (see origin). |
| Energy | by the electron are of colorates (see origin). |
| | Heat of: |
| | |
| * . | Formation, cal/gm 665 |
| | |

Ammonium Perchlorate

Origin: (c)

2. Mitscherlich first prepared, in 1832, crystals of amsonium perchlorate from barium perchlorate and amsonium sulfate (Pogg Ann 25, 300). T. Schlosing treated a hot solution of setium perchlorate with amsonium chloride, and on cooling, crystals of amsonium perchlorate were obtained (Comp rend, 73, 1269, [1871]). U. Alvisi treated a mixture of 76 parks of amsonium nitrate with 213 parts of sodium perchlorate, and obtained a crop of small crystals of amsonium perchlorate taken were purified by recrystallization from hot water (German Patent, 103,993, 7896). A. hiolati mixed magnesium or calcium perchlorate with amsonium chloride and crystals of amsonium perchlorate deposited from the solution of very soluble magnesium or calcium chloride (German Patent, 112, 682, 1899).

References: 4

- (a) W. B. Tomlinson, Jr., <u>Physical and Explosive Properties of Hilitary Explosives</u>, PATR Bo. 1372, 29 November 1943.
- (b) T. L. Davis, The Chemistry of Powder and Explosives, John Wiley and Sons, Inc., New York, 1943.
- (c) J. W. Mellor, A Comprehensive Treatise on Inorganic and Theoretical Chemistry, Vol. II, Longanums, Green and Co., London, 1982, p. 396.
 - (d) Also see the following Picatinny Arsenal Technical Reports on Ammonium Perchlorate:

| <u>o</u> | 1 | C.E. 3 | 4 | 5 | <u>6</u> | 2 |
|----------|-----|---------------------------|---------------------------|----------------------|----------|-----------------------|
| 100 | 521 | 8 ¹ 43 1783 | 354 60 4 854 | 1095 1725 2205 | 1726 | 1 0 49 1969 |

See fontnote 1, page 10.

Baratol

| Composition: % | Molecular Weight: | 125 |
|---|------------------------------|--------------|
| • | Oxygen Belence: | |
| Barium nitrate 67 | CO ₂ % | -3 |
| TNT 33 | CO % | +13 |
| | Density: gm/cc Cast | 2.55 |
| | Melting Point: °C | |
| C/H Ratio | Freezing Point: *C | |
| Impact Sonsitivity, 2 Kg Wt: | Boiling Point: °C | |
| Bureau of Mines Apparatus, cm 35 Sample Wt 20 riig | Refractive Index, no | |
| Picatinny Arsenal Apparatus, in. 11 | _ | |
| Somple Wt, mg 24 | n _m | |
| | n <u>∞</u> | |
| Friction Pendulum Test: | Vocuum Stability Test: | |
| Steel Shoe | cc/40 Hrs, at | |
| Fiber Shoe | 90°C | |
| PMI Pulled Investor Total | | • |
| Rifle Bullet Impact Test: Trials | 120°C | |
| Explosions % | 135°C | |
| Portials | 150°C | |
| Surned | | |
| Unaffected | 200 Gram Bomb Sand Test: | |
| Ordifected | Sand, gm | 26.8 |
| Explosion Temperature: °C | Secretivity to Initiation: | * |
| Seccids, 0.1 (no cap used) | Minimum Detonating Charge, g | m . |
| 1 | Mercury Fulminate | |
| 5 Ignites 385 | Leod Azide | 0.20 |
| 10 | Tetryl | 0.10 |
| 15 | | |
| 20 | Ballistic Mortar, % TNT: | |
| 75 C International Heat Test: | Trauxi Test, % TNT: | |
| % Loss in 48 Hrs | Plate Denii Test: (a) Method | 73/27 B |
| 103°C Heat Test: | Condition | Cast. |
| % Loss, 1st 48 Hrs | Confined | No |
| % Loss, 2nd 40 Hrs | Density, gm/cc | 2.52 |
| Explosion in 100 Hrs | Brisance, % TNT | ϵ_1 |
| | Detonation Rate: | |
| Flammability Index: | Confinement | • |
| | Candition | |
| Hygroscopicity: % | Charge Diameter, in. | |
| 30°C, 90% NI | Density gm/cc | |
| Volatility: | Rate, meters/second | |

£.

ींक दे

Barutol

| Bosotor Sensitivity Test: | Discompanition Equilies: |
|--|--|
| Condition | Oxygen, econsises |
| Tetryl, gm | (Z/sec) |
| Wex, in. for 50% Defonation 0.32 | Heat, kilocolorie/mole (AH, kcal/mol) |
| Wax, gm | Temperature Ronge, *C |
| Density, gm/sc 2.55 | |
| | Phiss 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 |
| Next of: | |
| Combustion, cal/grn | Armie Plate Impact Test: |
| | |
| Explanion, cai/gm | 60 mm Martur Cor scilles |
| Gas Volume, carpm | \$3% mert, Velocity, ft/sec |
| Formation, cal/gm | Aluminum Finances |
| Fesion, col/gm 75/25 Bers tol 2.8 (d) | |
| | 500-lb General Purpose Bombs: |
| ipecific Heet: coi/gm/*C (8) 75/25 Baratol | |
| | Plate Thickness, triches |
| | THE THEOLOGIA, HIGHES |
| -75 0.152 75 0.280 | |
| 0 0.147 85 0.213 | |
| 25 0.160 90 0.201 | |
| 50 0.229 100 0.171 | 1½ ~ (第二) (14. 1) (A. 1) (A. 1) (A. 1) (A. 1) |
| | 1 1944 J. 184 |
| lureling Rote: | |
| cm/yec | |
| | Bomb Drop Text: Kyen in figure (CC) (Sp. 426) |
| Thermal Conductivity: | 14.5° (14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 14.4. 1 |
| col sec/cm/°C | 37, 2000-16 Semi-Arzoer-Planting Bomb vs Conspetts: |
| THE STATE OF THE S | |
| Coefficient of Exponsion: | Max Safe Drop, ft |
| Linear, %7°C | 500 h General Purpose Bomb ys Consentes |
| | |
| Volume %/°C | Height, it |
| | |
| Graness, Melis' Scale: | The state of the s |
| | Unaffected (Control of Control of |
| eung's Medulus: | Low Order |
| - 그 - 그 | High Order |
| E', dynes/cm | |
| E, lb/inch² | 1006-16 Streyal Fuspace Somb vs Concrete: |
| Cercity, gm/cc | |
| | Height, ft |
| empressive Strongth: lb/inch² | Friale |
| | |
| | Unaffected |
| oper Barsure: | Low Order |
| C mm Mercury | Migh Order |
| | |
| | |
| | |
| | |
| | |

Baratol

Shaped Charge Effectiveness, THT = 100: 90 may 10E, M71 Projectile, Let WC-91: Gloss Cones Steel Cones Density, gm/cc Hole Volume Charge Wt, Ib Hole Depth **Total No. of Fragments:** Color: For TNT For Subject HE Principal Uses: Bomb filler 3 inch HE, M42A1 Projectile, Let KG-5: Density, gm/cc Charge Wt, Ib **Total No. of Fragments:** Method of Leading: Cast For TNT For Subject HE Leading D mily: gm/cc nent Velocity: ft/sec At 9 ft At 251/2 ft Density, gm/cc Method Dry Binst (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Peak Pressure Impulse Exudation Energy Preparation: Air, Confin Impulse The appropriate weight of barium nitrate heated to about 90°C is added to molton TMT contained in a melting vessel equipped with an agitator. Continue mixing until uniform, and load by pouring at the lowest practical temperature. I<mark>nder Weter:</mark> Peak Pressure Impulse Energy Origin: Paratol, an explosive containing barium nitrate and TNT, the proportions varied to suit the required purposes, was developed during World War I. Impulse Energy

Baratol

References: 5

- (a) D. P. MacDougail, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (b) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSED Report No. 5746, 27 December 1945.
 - (c) Also see the following Picatinny Arsenal Technical Reports on Baratol:

 0
 3
 6
 8

 2010
 1783
 2226
 2138

 2160
 2233

(d) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

See footnote 1, page 10.

Baronal

| Composition: | Molecular Weight: | 111 | |
|--|--------------------------------------|------|--|
| % Barium nitrate 50 | Oxygen Belence: CO ₂ % | -24 | |
| TNT 35 | CO % | - 7 | |
| Aluminum 15 | Density: gm/cc | 2.32 | |
| | Melting Point: *C | | |
| C/H Ratio | Freezing Point: *C | | |
| mpact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 30 | Builing Point: *C | | |
| Sample Wt 20 mg | Refractive Index, no | | |
| Picatinny Arsenal Apparatus, in. 12 Sample Wt, mg 22 | ກະ | | |
| | n ₂₀ | | |
| Friction Fondulum Test: | Vocuum Stability Test: | \ | |
| Steel Shoe | cc/40 Hrs, at | | |
| Fiber Shoe | 90°C | | |
| Rifle Bullet Impact Test: Trials | 100°C | | |
| % | 120°C | | |
| Explosions | 135°C | | |
| Partials | 150°C | | |
| Burned | 200 Grew Bamb Sand Test: | | |
| Unaffected | Sorad, ym | 39.8 | |
| Explosion Temperature: *C | Sonsitivity to initiation: | | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | | |
| l 5 Ignites 345 | Mercury Fulntinate | | |
| 10 | Lead Azide | 0.20 | |
| 15 | Tetryl | 0.10 | |
| 20 | Ballistic Mortar, % TNT: (a) | 96 | |
| | Treux! Test, % TNT: | | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: Method | | |
| 100°C Heat Test: | Condition | | |
| % Loss, 1st 48 Hrs | Confined | | |
| % Loss, 2nd 48 Hrs | Density, gm/cc | | |
| Explosion in 100 Hrs | Brisance, % TNT | | |
| Flammability Index: | Defonetion Rate: (b) Confinement | None | |
| 1. A. A. | Condition | Cest | |
| Hygroscopicity: % | Charge Diameter, in. | 1.0 | |
| Valetility: | Density, gm/cc | 2.32 | |
| | Rate, meters/second | 5450 | |

Beronal

| Fragmentation Test: Shaped Charge Effectiveness, TNT = 100: | | | | | | |
|---|---|--|--|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones | | | | | |
| Density, gm/cc | Hole Volume | | | | | |
| Charge Wt, ib | Hole Depth | | | | | |
| Total No. of Fragments: | Color: | | | | | |
| For TNT | Com. | | | | | |
| For Subject, ME | Principal Uses: Bomb filler | | | | | |
| 3 Inch HE, M42A1 Projectile, Let KC-5: | | | | | | |
| Density, gm/cc | | | | | | |
| Charge Wt, Ib | | | | | | |
| Total No. of Fragments: | Method of Leading: Cast | | | | | |
| For TNT | William or Committee Control | | | | | |
| For Subject HE | | | | | | |
| | Louding Density: gm/cc 232 | | | | | |
| Fragment Valocity: ft/sec | | | | | | |
| At 9 ft | | | | | | |
| At 251/2 ft | Storage: | | | | | |
| Density, gm/cc | Mark and South | | | | | |
| | Method Dry | | | | | |
| Hest (Relative to TNT): | Hazard Class (Quantity-Distance) Class 9 | | | | | |
| Air: | Compatibility Group Group I | | | | | |
| Peak Pressure | | | | | | |
| Impulse | Exudation | | | | | |
| Energy | | | | | | |
| Air, Confined: | Preparation: | | | | | |
| Impulse | Procedure same as described under Baratol | | | | | |
| | except aluminum is added to the barium ni- | | | | | |
| Under Weter: | trate-TNT molton mixture under agitation | | | | | |
| Peak Pressure | until uniformity in comparison is obtained. | | | | | |
| impulse | Booster Sensitivity Test: | | | | | |
| Energy | (c) | | | | | |
| | Condition Cast Tetryl, gm 100 | | | | | |
| Underground: | Wax, in. for 50% Detonation 0.86 | | | | | |
| Dook Pressure | | | | | | |
| Peak Pressure | Density, gm/cc 2.32 | | | | | |
| Impulse | | | | | | |
| | Density, gm/cc 2.32 Heat of: | | | | | |
| Impulse | Heat of: | | | | | |
| Impulse | | | | | | |

Beronel

References: 6

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosivis, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) G. ... Messerly, The Rate of Detonation of Various Explosive Composite, OSRD Report No. 1219, 22 February 1943.
- N. D. Burwits, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report Bo. 5611, 15 January 1946.
 - (e) D. P. MacDougall, <u>Methods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.
- (d) Arthur D. Little Report, Study of Pure Explosive Compounds, Part III, Correlation of Composition of Mixture with Performance, Contract No. DA-19-020-ORD-12, 1 May 1950.
- (e) S. J. Lowell, <u>Propagation of Detonation in Long and Marrow Columns of Explosives</u>, PATR No. 2136, February 1955.

⁶See footnote 1, page 10.

AMCP 706-177

Black Powder

| Composition: 96 | Melecular Weight: | 84 |
|---|--|----------|
| Potessium nitreta 74.0 | Gaygen Belence: CO ₂ % CO % | -55 |
| Sulfur 10.4 | | |
| Charcoal 15.6 | Density: g:::/cc Making Point: *C | Variable |
| C/H Ratio | Freezing Point: *C | |
| Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg Picatinny Ansenal Apparatus, in. 16 Sample Wt, mg 16 | Beiling Point: *C Refrective Index, nonnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnn | |
| Sompic Wi, mg | n _m | |
| Frience Pendelum Test: Steel Side Snaps Fiber Show Unaffected | Vecuum Stubility Test: cc/40 Hrs, at 90°C 100°C | 0.5 |
| Riffle Bullet Impact Test: Trials Kaplasians | 120°C 135°C | 0.5 |
| Portiols Burned Unaffected | 200 Grem Bomb Sead Test: Sand, gm | 8 |
| Explosion Temperature: °C Seconds, 0.1 (no cap used) 510 i 490 5 Ignites 427 i0 356 | Sensitivity to Initiation: Minimum Detonating Charge, Mercury Fulminate Lind Azide Tetryl Sensitive to igniting fue Bellistic Morter, % TNT: | ses |
| 20 | Trougi Test, % TNT: (a) | 10 |
| 75°C International Heat Test: % Loss in 48 Hrs 0.31 160°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs | Plate Dent Test: Method Condition Confined Density, gm/cc | |
| Exclosion in 100 Hrs | Brisance, % TNT | |
| Flammebility Index: | Detonation Rate: Confinement Condition | |
| Hygrescapicity: % 25°C, 75% RH 0.75 25°C, 90% RH 1.91 30°C, 90% RH 2.51 | Charge Diameter, in. Density, gm/cc | 1.6 |
| Volatility: | Density, grit/cc | 2.0 |

Black Powder

| regmentation Test: | | Sheped Charge Effectiveness, TNT = 100: | | | |
|-------------------------------------|----------|---|--|--|--|
| 90 mm HE, M71 Projectile, Let WC- |)1: | Glass Cones Stee! Cones | | | |
| Density, gm/cc | | Hole Volume | | | |
| Charge Wt, Ib | | Hole Depth | | | |
| Total No. of Fragments: | | Color: Black | | | |
| For TNT | * • | Com. Dieck | | | |
| For Subject HE | | Principal Uses: 1. Igniter powder | | | |
| 3 inch HE, M42A1 Projectile, Let KC | . | 2. Time rings (fuzes) | | | |
| Density, gm/cc | | | | | |
| Charge Wt, Ib | | | | | |
| Cicigo VVI, io | | | | | |
| Total No. of Fragments: | | Method of Looding: 1. Loose (granulated) | | | |
| For TNT | | 2. Pressed | | | |
| For Subject HE | | Legitor Density: cm/cr psi x 10 ³ | | | |
| | | | | | |
| regment Velocity: ft/sec | | 25 50 60 65 70 75 1.74 1.84 1.86 1.87 1.88 1.89 | | | |
| At 9 ft At 251/2 ft | | Storage: | | | |
| Density, gm/cc | | Method Dry | | | |
| liest (Relative to TNT): | | Hazard Class (Quantity-Distance) Class 9 | | | |
| Aire | | Compatibility Group Group 0 | | | |
| Peak Pressure | | | | | |
| Impulse | | Exudation None | | | |
| Energy | | : | | | |
| | | 100°C Vacuum Stability Test, | | | |
| Air, Cenfined: Impulse | | cc gas/40 hrs: | | | |
| ··· qualita | | Initial Value 0.5 After 2 hours at 65°C 0.86 | | | |
| Under Water: | | After 2 hours at 65°C, 75% RH 1.46 | | | |
| Peak Pressure | | Sensitivity to Electrostatic | | | |
| Impulse | | Discharge, Joules: (b) | | | |
| Energy | | Unconfined >12.5 | | | |
| Underground: | | Confined 0.8 | | | |
| Peak Pressure | | Compatibility with Metals: | | | |
| impulse | | Dry - Compatible with all metals when | | | |
| Energy | | moisture content is less than 0.20 | | | |
| Initiating Efficiency: | | Wet - Attacks all common metals except steinless steel. | | | |
| Grams Required to Initiate | | Heat of: | | | |
| Igniter Comp K+31 | 2.0 | | | | |
| Igniter Comp K-29 | 2.3 | Explosion, ca!/qm 684 Gas Volume, cc/gm 271 | | | |

Preparation:

willow or alder charcoal, flour of sulphur and 2-3% of water are placed in a tumbling barrel and mixed for a short period (about 1/2 hour). The mixture is transferred to a "wheel mill" and crystalline potassium nitrate containing 3-4% moisture is added and the mixture is in orporated for several hours. During the incorporation period the mixture is kept damp (2-3% moisture) by adding water at intervals. The mill cake is then pressed at 5000 psi between aluminum plates. The pressed cakes are broken up between rubber or wood rolls. The material is screened and the various particle sizes are separated as desired. The screened material is then transferred to convast rays and dried in hot air owens at 60°C. If it is desired to glaze the black powder, the material before drying is polished by rotation in a tumbling barrel to give it a smooth surface. It is next screened to remove the dust. The smooth particles are then placed in a wooden barrel and rotated with graphite. The material is again screened to remove the excess graphite, and dried. Material finer than \$40 U. S. Sieve is not graphited.

WARNING

The batches of black powder must be of sufficient size to cover the bed of the "wheel mill." If the wheels run off on the bare bed, explosions usually result.

Origin:

The exact date of the discovery of black powder is unknown. Historians attribute its discovery to the Chinese, Hindus or Arabs. The Greeks used it during the 7th Century. Marcus Graecus in the 9th Century and Roger Bacon in the 13th Century described compositions similar to the present powder. Beginning with the 16th Century, the composition of black powder containing potassium nitrate, charcoal and sulfur has remained unchanged with respect to the proportionality (75/15/10) of the ingredients.

Destruction by Chemical Decomposition:

Black powder can be desensitized by leaching with water to dissolve the potassium nitrate. The washings must be disposed of separately because the residue of sulfur and charcoal is combustible but not explosive.

References: 7

- (a) Fh. Naoum, Nitroglycerine and Nitroglycerine Explosives, Baltimore, 1928.
- (b) F. W. Brown, D. H. Kusier and F. C. Gibson, Sensitivity of Emplosives to Initiation by Electrostatic Discharges, U. S. Department of the Interior, Bureau of Mines RI 3852, 1946.
 - (c) Also see the following Picatinny Arsenal Technical Reports on Black Powder:

See footnote 1, page 10.

| Black Powder AMCP 706-177 | | | | | | | | | | |
|-----------------------------------|--|--|--|---|---|--|--|---|---|--|
| <u>o</u> | 1 | 2 | 3 | 4 | ٤ | <u>6</u> | I | <u>8</u> | 2 | |
| 250 710 850 1010 1450 | \$1 471 661 901 1111 1241 1451 1541 1711 1951 2051 | 222 \$72 \$72 \$72 \$92 582 762 872 1022 1712 1802 1912 | 163 363 453 843 1043 1153 1243 1393 1493 1643 1813 1843 1973 | 354 554 554 554 554 654 664 774 844 1154 1244 1504 | 65 415 545 605 1145 1275 1815 1885 1905 1915 | 56 176 356 686 746 1256 1316 1536 1576 1586 1946 | 347 407 437 547 757 847 1097 1737 1797 1807 1827 | 188 318 428 558 598 608 618 698 898 1068 1388 1528 1778 1838 1838 | 379 819 839 849 859 1259 1309 1339 1349 1589 1739 1869 | |

AMCP 706-177

1,2,4-Butanetriol Trinitrate (BITN) Liquid

| Composition: | | Moleculer Weight: (C4H7N309) | 241 | | | |
|--|------|--------------------------------|--------|--|--|--|
| c 19.9 | | Oxygen Belence: | | | | |
| H ₂ C-ONO ₂ | ! | CO. % CO % | -17 | | | |
| и 2.9 г. | | CO % | 10 | | | |
| N 17.5 / HC-ONO | | Density: gm/cc Liquid | 1.52 | | | |
| 0 59.7 | | Melting Point: °C | | | | |
| H ₂ Č-ONO ₂ C/H Ratio 0.13 | | Freezing Point: °C | | | | |
| impact Sanditivity, 2 Kg Wt: | FO | Bailing Point: °C | | | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | 58 | Refrective Index, 120 | 1.4736 | | | |
| Picatinny Arsenal Apparatus, in. | ≰l | nº | 114130 | | | |
| Sample Wt, mg | _ | n D | | | | |
| Friction Pendulum Test: | | Vocuum Stability Test: | | | | |
| Steel Shoe | | cc/40 Hrs, at | | | | |
| Fiber Shoe | | 90°C | | | | |
| Rifle Bullet Impa : Test: Trials | | 100°C | 2.33 | | | |
| | | 120°C | | | | |
| % Explosions | | 135°C | | | | |
| Partials | | 150 ⁻ C | | | | |
| Burnzd | • | 200 Gram Romb Send Test: | | | | |
| Unaffected | | Sand, gm | 48.6 | | | |
| Explosion Tomperature: "C | | Sensitivity to Initiation: | | | | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, gr | 1 | | | |
| 1 | • | Mercury Fulminate | | | | |
| 5 Decomposes 23 | D | Leod Azide | 0.20 | | | |
| 10 | | Tetry! | 0.10 | | | |
| 15 20 | | Bellistic Morter, % TNT: | | | | |
| | | Treezi Test, % TNT: | | | | |
| 75°C International Neat Tost: % Loss in 48 Hrs | | Plate Dent Test: | | | | |
| | | Method Condition | | | | |
| 100 C Heet Test: | | Condition | | | | |
| % Loss, 1st 48 Hrs | 1.5 | | | | | |
| % Loss, 2nd 48 rins | 1.2 | Density, gm/cc Brisonce, % TNT | | | | |
| Explosion in 100 Hrs | None | | | | | |
| Flemmebility Index: | | Detenation Rate: | | | | |
| The state of the s | | Confinement | | | | |
| Hygroscopicity: % (a) | | Condition | | | | |
| 100°F, 95% RH, 24 hrs | 0.14 | Charge Diameter, in | | | | |
| Veletility: | | Density, gm/cc | | | | |
| 60°C, mg/cm²/hr | 46 | Rate, meters/second | | | | |

1,2,4-Butanetriol Trinitrate (BTIN) Light

| regeneration Test: | Shaped Charge Effectiveness, TNT % 100: |
|---|--|
| 90 cnm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones |
| Density, gm/cc | Hale Valume |
| Charge Wt, Ib | Hole Depth |
| Total 14s. of Fragments: | Color: Yellow oul |
| For TNT | Color: Yellow oil |
| For Subject ME | Principal Uses: Explosive plasticizer for |
| 3 inch HE, M42A1 Projectile, Let K6.5 | nitrocell:lose |
| Density, gm/cc | } |
| Charge Wt, Ib | |
| Total No. of Fragments: For TNT | Method of Louding: |
| For Subject HE | |
| | Looding Density: gm/cc 1.52 |
| agmont Velocity: ft/sec At 9 ft At 25½ ft | Storage: |
| Density, gm/cc | /Aethod |
| et (Relative to TNT): | Hazard Class (Quantity-Distance) |
| Air: | Compatibility Group |
| Peak Pressure | |
| †mpulse | Exudation |
| Energy | <u> </u> |
| Air, Confined: | Solubliity is Water, (a) gm/100 gm, et: |
| Under Weter: | 20 0 0.04 60°0 0.15 |
| Peak Pressure | Solubilit of Water in. (8) |
| Impulse | 5m/100 gm: 0.04 |
| Energy | Solubility, gm/100 gm. |
| Underground: | 8 25°C, 1c: |
| Peak Pressure | Alcohol |
| impulse Energy | 2:1 Ether:Alcohol « Acatone » |
| les . of: (E) | Wis voite, reprigations: (a) |
| Combistion rel/m (1) | |
| Exp Deion, col/m. 16.7 | 10 to 10 10 10 10 10 10 10 10 10 10 10 10 10 |
| Gas Volume, comma | 1 |

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1,2,4-Butanctriol Trinitrate (BTTK) Liquid

Preparation (Laboratory Procedure):

To a cooled mixture of 73.8 gm of 100% nitric acid, 46.2 gms of 106.2% sulfuric acid and 60.0 gm of 96.1% sulfuric acid, 30 gms of the original (or redistilled) 1,2,4-butanetriol was added dropwise with agitation for a period of thirty minutes. The temperature of the reaction mixture was kept at 0°-5°C. When the agitation was completed stirring was continued for one and one-half hours. The mixture was powed into ice water, and the resulting oil suspension was extracted with three 100 milliliter portions of other. The combined other extracts were washed with water, then with a 5% sedium bicarbonate solution and finally with water. The neutralised extract was dried with anhydrous calcium chloride and then the other was weaponated. The yellow oil was dried in a vacuum desicostor over anhydrous calcium chloride until the material was brought to constant weight.

Origin:

1,2,4-butanetriel was first synthesized by Wagner and Ginsberg in 1894 by oxidizing allyl carbinol with potassium perconganate under mild conditions (Ber 27, 2437). Recently the U. S. Rubber Laboratory, under the direction of P. Tawney, devised a new synthesis carried out with allyl acetate and formaldehyde to give 1,2,4-butane triacetate which was readily hydrolysed to butanetriol (U. S. Rubber Company Guarterly Report, May 1948). Working with pure 1,2,4-butanetriol prepared by an improved technique of the Wagner method, the U. S. Ruval Imboratory in 1948 nitrated the butanetriol on a laboratory and a pilot plant scale (Reference a).

Ruferences: 3

- (a) J. A. Gallaghan, F. Macri, J. Bednarik, and F. McCollum, The Synthesis of 1,2,4-Butanetriol and the Evaluation of Its Trinitrate, U. S. Naval Powder Pactory Technical Report No. 19, 10 September 1948.
- (b) Also see the following Picatinny Arsens: Technical Reports on Butanetriol Trinitrate: 1755 and 2786.

⁸See rootnote 1, page 10.

| Composition: | | Melecular Weight: | | 227 |
|--|----------|--|----------|---|
| | | Oxygen Belence: | | |
| RDX 91 | | CO. % CO % | | -48 -23 |
| Wax 9 | | | | |
| | | Density: gm/cc 12,0 | 00 pai | 1.65 |
| | | Melting Point: *C. | | |
| C/H Ratio | | Freezing Point: 'C | | |
| mpact Sanaktivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | 100+ | Beiling Point: *C | | |
| Sample Wt 20 mg | | Refrective Index, 1120 | | |
| Picatinny Arsenal Apparatus, in. Sample Wt, mg | 16 17 | n _{2s} | | |
| ¥ - | -, | n <mark>⊊</mark> | | |
| riction Pondulum Test: | | Vacrum Stability Test: | | *************************************** |
| Steel Shoe Unaffe | | cc/40 Hrs, at | | |
| Fiber Shoe Unaffe | eted | 90°C | | |
| Rifts Bullet Impact Test: Trials | | 120°C | | 0.3 |
| - % | | 135°C | | 0.6 |
| Explosions 0 | | 150°C | | |
| Portials 0 Burned 0 | | | | |
| Unaffected 100 | | ! 200 Gram Bemb Sand Test Sand, gm | E) E | |
| | | | | 51.5 |
| Explosion Temperature: "C Seconds, 0.1 (no cap used) | | Sensitivity to Initiation: Minimum Detenating C | horne om | |
| 1 | | Mercury Fulminate | ande' Au | 0.22* |
| 5 Decomposes 250 | | Lead Azide | | 0.25* |
| 10 | | * Alternative initiat | ing here | |
| 15 | | Bellistic Morter, % TNT: | | |
| 20 | | Troug! Test, % TNT: | (a) | 13) |
| S'C International Heat Test: | | Plate Dont Tut: | (b) | |
| % Loss in 48 Hrs | | Method | B | В |
| 00°C Heat Tast: | | Condition | Pressed | Pressed |
| % Loss, 1st 48 Hrs | 0.15 | 1 | No | No |
| % Loss, 2nd 48 Hrs | 0.15 | | 1.61 | 1.20 |
| Explosion in 100 Hrs | None | Brisance, % TNT | 126 | 75 |
| amachility Indon. | 100 | | (c) | |
| lemmebility Index: | 195 | Confinement | | None |
| lygrescopicity: % 30°C, 90% RH | 0.0 | Condition | | Pressed |
| | | Charge Diameter, in. Density, gm/cc | | 1.0 |
| electificy: 50°C, 15 days | 7.03 | Density, girit cc | | 1.59 |

| Fregmentation Test: | | Shapes Charge Effectiveness, TNT = 100: |
|---|--------------|---|
| 90 mm HE, M71 Projectile, Lot | WC-91: | Glass Cones Steel Cones |
| Density, gm/cc | 1.62 | Hole Volume |
| Charge Wt, Ib | 2.102 | Hole Depth |
| Total No. of Fragments: | | Color: White-buff |
| For TNT | 703 | Color: White-buff |
| For Sucject HE | 1138 | Principal Uses: HE, SAP, AP projectiles; |
| 3 inch HE, M42A1 Projectile, Lo | KC-5: | Shaped Charges |
| Density, gm/cc | 1.64 | |
| Charge Wt, Ib | 0.861 | |
| Total No. of Fragments: | | Method of Looding: Pressed |
| For YNT | 514 | Treased |
| For Subject HE | 710 | Leading Density: om/cc psi x 10 ³ |
| Engage and Valuation to the same | | 3 12 |
| Fragment Valocity: ft/sec At 9 ft At 25½ ft | 2800 2530 | 1.47 1.65 |
| Density, gm/cc | 1.61 | |
| bersity, gilly cc | | Method Dry |
| Blast (Relative to TNT): | | liazard Class (Quantity-Distance) Class 9 |
| Air: | | Compatibility Group Group I |
| Peak Pressure | | Endation 3 not exude at 65°C when waxe. |
| Inipulse | | multing sharply at or above 75°C are used. |
| Energy | | Preparation: |
| Air, Confined: | | |
| Impulse | | A water slurry of RDX is heated to 100°C with agitation. Wax and a wetting agent are added and the mixture, under agitation, is |
| Under Water: | | cooled below the melting point of the wax. |
| Peak Pressure | | The wax coated RDX is collected on a filter |
| Impulse | | and air dried at 75°C. |
| Energy | | Effect of Temperature on Fate of Detonation: (e) |
| Undergreend: | | 16 hrs at, °C -54 21 |
| Peak Pressure | | Density, gm/cc 1.51 1.51 Rate, m/sec 7600 7620 |
| Impulse Energy | | Booster Sensitivity Test: (d) |
| Energy | | |
| | | Condition Pressed Tetryl, gm 100 |
| | | Wax, in. for 90% Detonation 1.70 |
| | | Density, gm/cc 1.62 |
| | | Heat of: |
| | | Oumbustion, cal/gm 1210 |

Compatibility with Metals:

Dry - Aluminum, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with nickel or zinc are unaffected. Copper, magnesium, magnesium-aluminum alloy, brass and mild steel plated with cadmium or copper are slightly affected.

Wet - Stainless steel is unaffected. Copper, aluminum, magnesium, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are slightly affected.

Origin:

Developed by the British during World War II as RDX and beeswax. Subsequent changes in the United States replaced beeswax with synthetic wares, changed the granulation of RDX and improved the method of manufacture.

Destruction by Chemical Decomposition:

RDX Composition A-3 (RDX/wax, 91/9) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium hydroxide. Boiling of the solution is continued for one-half hour.

References: 9

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (d) L. C. Smith and S. R. Valton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, dated 15 June 1949.
- (e) W. F. McGarry and T. W. Stevens, Detonation Ret 3 of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383. November 1956.
 - (f) Also see the following Picatinny Arsenal Technical Reports on RDX Composition A-3:

| <u>o</u> | <u>1</u> | 2 | 3 | 4 | 2 | <u>6</u> | 7 | 8 | 9 |
|--------------|--------------|--------------|------|------------------------------|--|-----------------------|----------------------|---------------------------------------|--------------|
| 1380 1910 | 1451 1761 | 1492 2112 | 1493 | 1424 1614 1634 2154 | 1325 1585 1595 1715 1835 2235 | 1556 19 3 6 | 1637 1737 1797 | 1336 1388 1723 18 3 8 | 1639 2179 |

⁹See footnote 1, page 10.

Composition B

| Semposition: 96 | | Melecular Weight: | 224 |
|--|-----------------|--------------------------------------|------------|
| RDX 60 | | Oxygen Belence: CO ₂ % | -43 |
| TNT 40 | | CO % | 10 |
| | | Density: gm/cc Cast | 1.65 |
| Wax, added 1 | | Melting Point: "C (1) | 78-80 |
| C/H Ratio | | Freezing Point: *C | |
| npact Sanakivity, 2 Kg Wit: | 75 | Soiling Point: 'C | |
| Bureou of Mines Apparatus, cm Somple Wt 20 mg | 12 | Refrective Index, no | |
| Picatinury Arsenal Apparatus, in. | 14 | n <u>R</u> | |
| Sample Wt, mg | 19 | n _s | |
| riction Pendulum Test: | | Vocuum Stability Test: | |
| Steel Shoe Unaffect | | cc/40 Hrs, at | |
| Fiber Shoe Unaffect | ted | 90°C | |
| Liffe Bullet Impact Test: Trials | | 160.C | 0.7 |
| • | | 120°C | 0.9 |
| Explosions % | | 135°C | |
| Partials 13 | | 150°C | 11+ |
| Burned 4 | | 200 Grem Somb Sond Test: | |
| Unaffected 80 | | Sand, gm | 54.0 |
| uplation Temperature: 'C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) 526 | | Minimum Detonating Charge | |
| 1 368 | | Mercury Fulminate | 0.22* |
| 5 Decomposes 278 | | Lead Azide | 0.20* |
| 10 255 | | Tetryl * Alternative initiating | charges |
| 15 > 25∪ 20 > 250 | | Bellistic Morter, % TNT: (a) | |
| | | Trouzi Test, % 1NT: (b) |) 130 |
| 5°C International Hout Tost: % Loss in 48 Hrs | | Plate Deat Test: (c) | • |
| | | Method | B 60-44 |
| 90°G Heat Test: | | Condition | Cast |
| % Loss, 1st 48 Hrs | 0.2 | Confined | No |
| % Loss, 2nd 48 Hrs | 0.2 | Density, gm/cc | 1.71 |
| Explosion in 100 Hrs | None | Brisance, % TNT | 132 |
| namebility Index: | 177 | Detenation Rate: Confinement | None |
| | - 1. | Condition | None |
| tygrescopicity: % 30°C, 90% RH | 0.02 | | 1.0 |
| , 2, 10 30 0, you ldi | | Charge Diameter, in. | 1.68 |
| /eletility: | | Density, gm/cc | |
| | | Rate, meters/second | 7540 |

Composition B

| Beater Schellivity Test. Condition | (d) Cast | Decomposition Equation: Oxygen, atoms/sec (Z/sec) | • | |
|--|----------------|---|-------------------------|-------------------|
| Tetryl, gm | 100 | Heat, kilocolorie/mok | • | |
| Wax, in. for 50% Detonation | 1.40 | (ΔH, kcal/mol) | | |
| Wax, gm | _ | Temperature Range, ⁴ | C | |
| Density, gm/cc | 1.69 | Phase | | |
| Heat of: Combustion, col/gm | (e) 2790 | Armor Plate Impact Test | : | (e) |
| Explosion, cal/gm | 1240 | 40 mm Morter Project | 110a | |
| Gas Volume, cc/gm | | 50% Inert, Velocity | | 209 |
| Formation, cal/gm | | Aluminum Sineness | | - - |
| Fusion, cal/gm (1) | ૄ. 0 | | | |
| | | 500-lb General Purpos | e Bembe: | |
| Specific Heat: cal/gm/*C (2) | | Plate Thickness, inc | ches | |
| | | | Trials | % Inert |
| -75 0.23 5 75 | 0.376 | 1 | 4 | 100 |
| 0 0.220 85 25 0.25 90 | 0.354 0.341 | 11/4 | 6 | 50 |
| 50 0.305 100 | 0.312 | 11/2 | 2 | 0 |
| | - | 134 | 0 | |
| Thermal Conductivity: cxil/sec/cm/*C | | Bomb Drop Test: T7, 2000-lb Somi-Arm | nor-Piercing (| lemb vs Cencro'e: |
| Coefficient of Expension: | | Max Safe Drop, ft | | |
| Linear, %/*C | | 500-lb General Purpo | se Bomb vs (No Seal | Concrete: Seal |
| Volume, %/°C | | Height, ft | 4000 | 400 |
| | | Trials | 65 | 3>) |
| Hardness, Mohs' Scale: | | Unafrected | 5 8 | 3 6 |
| | | Low Order | 2 | 2 |
| Young's Medulus: | | High Order | 5 | 1 |
| E', dynes/cm² | | | | _ |
| E, Ib/inch² | | 1000-lb General Purp | ose Bomb vs (| Concreto: |
| Density, gm/cc | | | | |
| | | — Height, ft | | |
| Compressive Strongth: lb/inch ² (b) | 1610-2580 | Trials | | |
| Density, gm/cc | 1.68 | Unaffected | | |
| Vapor Pressure: | | Low (1er | | |
| *C mm Mercury | | High Order | | |
| | | | · —— | |

Composition B

| Fragmentation Test: | | Shaped Charge Effectiveness, TNT = 100: | |
|----------------------------------|---------------|---|------------|
| 00 mm ME M71 0-1-41-4 | WC 01. | (g) (h) | |
| 90 mm HE, M71 Projectile, Lat | | Glass Cones Steel Conec | |
| Density, gm/cc | 1.65 | Hole Volume 178 162 | |
| Charge Wt, Ib | 2.187 | Hole Depth 125 148 | |
| Total No. of Fragments: | | Color: Yellow-brown | |
| For TNT | 703 | ieilow-brown | |
| For Subject HE | 998 | Principal Uses: Fragmentation bombs, | |
| 3 inch HE, M42A1 Projectile, Lot | KC-5: | projectiles, grenade | s, shaped |
| Density, gm/cc | 1.67 | charges | |
| Charge Wt, Ib | 0.662 | | |
| Total No. of Fregments; | | Mathed of Lordina | |
| For TNT | 514 | Method of Loading: (**) | i |
| For Subject HE | 701 | Loading Density: gm/cc 1.6 | ٦ |
| Fragment Velocity: ft/sec | | | - |
| At 9 ft | 2940 | | |
| At 25½ ft | 2680 | Storege: | |
| Density, gm/cc | 1.68 | Method Dr | |
| | | · | ry |
| liest (Relative to TNT): | (r) | Hazard Class (Quantity-Distance) C1 | lass 9 |
| Air: | | Compatibility Group G1 | roup I |
| Peak Pressure | 110 | | • - |
| Impulse | 110 | Exudation Very slight when stored | at 71°C |
| Energy | 116 | | |
| Air, Confined: | | Origin: | |
| Impulse | 7 5 | RDX Composition B was developed b | ur +h- |
| | | British between World War I and Wor | |
| Under Weter: | | It was standardized by the United S | |
| Peak Pressure | 110 | early in World War II. | |
| Impulse | 10 8 | Effect of Temperature on | |
| Energy | 121 | Rate of Detonation: | (i) |
| Underground: | | 16 hrs at, °C -54 | 24 |
| Peak Pressure | 104 | Density, gm/cc 1.69 | 1.69 |
| Impulse | 97 | Rate, m/sec 7720 | 7660 |
| Energy | | Bulk Modulus at Room | (;) |
| Crater radius cubed | 107 | Tempersture (25°-30°C): | |
| | , | % Wex in Comp B 1 2 | 3 |
| | | Dynes/cm ² x 10 ⁻¹⁰ 5.10 3.50 | 2.34 |
| | | Density, nm/cc 1.72 1.70 | 1.47 |
| | | Viscosity, poises: | 3 1 |
| | | Temp, 6300 9500 | 3.1 2.7 |

Compatibility with Metals:

Dry - Magnesium, aluminum, magnesium-aluminum alloy, mild steel, stainless steel, mild steel coated with acid-proof black paint and mild steel plated with zinc or nickel are unaffected. Copper, brass and mild steel plated with copper or cadmium are slightly affected.

Wet - Aluminum and stainless steel are unaffected. Copper, brass, mild steel, mild steel coated with acid-proof black paint and mild steel plated with cadmius, copper, nickel or zinc are slightly affected. Magnesium and magnesium-aluminum alloy are more heavily affected.

Preparation:

Water wet RDX is added slowly with stirring to molten Two melted in a steam-jacketed kettle at a temperature of 100°C. Some water is poured off and heating and stirring are continued until all moisture is evaporated. Wax is then added and when thoroughly mixed, the composition is cooled to a satisfactory pouring temperature. It is east directly into ammunition components or in the form of chips when Composition B is to be stored.

Destruction by Chemical Decomposition:

RDX Composition B is decomposed in 12 parts by weight of technical grade acetone heated to 45°C. While this is stirred vigorously, there is added 12 parts of a solution, heated to 70°C, of 1 part sodium sulfide (Na₂S'9H₂O) in 4 parts water. The sulfide solution is added slowly so that the temperature of the acetone solution does not rise above 60°C. After addition complete, stirring is continued for one-half hour.

References: 10

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensiti..ty Tests; Performance Tests, OuRD Report No. 5746, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military Righ Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Smmittee of Divisions 2 and 8, NDRC, Report on HF' and Tritonal, CTRD Report No. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W572-ORD-5723.
- (h) Eastern Laboratory du Pont, <u>Investigation of Cavity Fffect</u>, Final Report, E Lab du Pont, Contract W-672-ORD-5723, 18 September 1943.
- (i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November, 1956.

¹⁰See footnote 1, page 10.

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Composition B

(j) W. S. Crewer, Bulk Compressibility Data on Several High Explosives, NAVORD Report No. 4380, 15 September 1955.

(k) Also see the following Picatinny Arsenal Technical Reports on RDX Composition B:

| <u>o</u> . | 1 | 2 | 3 | 4 | 5 | <u>6</u> | I | <u>8</u> | 2 |
|--------------------------------------|------------------------------|----------------------|--|------------------------------|--|--|--|--|--------------------------------------|
| 1360 1530 2100 2160 2190 | 1211 1451 2131 2151 | 1402 1482 1592 | 1313 1433 1803 1983 2053 2063 2103 2233 | 1424 1944 2004 2104 | 1325 1435 1585 1595 1865 1885 2055 2125 | 1466 1476 1556 1756 1956 2257 | 1207 1437 1457 1737 1797 2007 2147 | 1338 1368 1438 1458 1688 1728 1828 | 1339 1379 1469 1819 7019 |
| | | | E233 | | 2155 2175 2235 | | | 1978 2008 2138 | |

(1) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Fusion Explosives, PATR No. 2504, January 1959.

Composition B, Desensitized

| Composition: | <u>I*</u> | 11** | Molecular Weight: | <u>]*</u> e Cyclouite | II++ See Comp R |
|--|-----------------|--------------|-----------------------------------|--------------------------|--------------------|
| RDX | 60 40 | 55.2 40.0 | Oxygen Balence: | | |
| TNT | 4 0 | 40.0 | | e Cyclonite | See Comp B |
| Wax, added, (Stanolind or Aristowax, 1650/ 1700F) | 5 | | 1 | e Cyclonite | See Comp B |
| Vinylseel (MA28-14), edded | 2 | | Density: gin/cc Cast | 1.65 | 1.65 |
| Vistanex (Bl20) Albecer Wax | | 1.2 3.6 | Melting Point: *C | · | |
| C/H Ratio | | | Freezing Point: °C | | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | <u>I*</u> 95 | <u> </u> | Boiling Point: *C | | |
| Sample Wt 20 mg | •• | | Refractive Index, no | | |
| Picatinny Arsenal Apparatus, in. | 14 | 13 | n _o | | |
| Sample Wt, mg | 17 | 16 | = | | |
| | | | n _m | | |
| Friction Pendulum Test: Stud Shoe Unaffect | -e3 | | Vacuum Stability Test: | <u>I*</u> | 11** |
| | | | cc/40 Hrs, at 90°C | | |
| Fiber Shoe Unaffect | æu | | - 100°C | | |
| Rifle Bullet Impect Test: Trials | | | · · | 0.99 | 0.92 |
| % | I* | 11** | 120°C | 0.33 | 0.72 |
| Explosions ~~ | 0 | 0 | 135°C | • • • | |
| Partials | 0 | 0 | 150°C | 11+ | 11+ |
| Burned | 5 | 0 | 200 Grem Bomb Sond Test: | <u>I*</u> | II** |
| Unoffected | 95 | 100 | Sand, gm | 52.7 | 55.0 |
| Explosion Te preture: °C | <u>I*</u> | II** | Sensitivity to Initiation: | <u>I*</u> | II** |
| Seconds, 0.1 (no cap used) | | | Minimum Detonating Ch | iorge, gm | |
| l 5 Decomposes 2 | 260 | 070 | Mercury Fulminate | | |
| • | 200 | 270 | Lead Azide | 0.22 | 0.26 |
| 10 15 | | | Tetryl | | |
| 20 | | | Bellistic Morter, % TNT: | | |
| | | | Trouzi Test, % TNT: | | |
| 75°C International Heat Test: % Loss in 48 Hrs | | | Plata Dent Test: Method | | · · · · · · |
| 10. C Heet Test: | <u>I*</u> | II** | Condition | | |
| % Loss, 1st 48 Hrs | 0.05 | 0.12 | Confined | | |
| % Loss, 2nd 48 Hrs | 0.19 | 0.18 | Density, gm/cc | | |
| Explosion in 100 Hrs | None | None | Brisance, % TNT | | |
| Flammability Index: | · | | - Detonation Rate: Confinement | | |
| | | | 1 | | |
| Hygrescapicity: % | | | Condition | | |
| 30°с, 90% RH | 0.00 | 0.00 | Charge Diameter, in. | | |
| Voistifity: | Nil | Nil. | Density, gm/cc | | |
| · | 74T T | 44.4 | Rate, meters/second | | |

^{*}Desensitized Comp P, designated I, uses emplaified wax. **Desens'tized Comp B, designated II, uses costed RDX.

Composition B, Desensitized

| Fragmentation Test: | | | Shaped Chan | pe Effectiven | ess, TNT = 10 | 10: |
|-----------------------------------|-------------|--------------|-------------------------|---------------|--|-------------|
| 90 mm HE, M71 Projectile, | Let WC-91: | | | Gloss on | nes Steel C | ones |
| Density, gm/cc | | | Hole Volum | me | | |
| Charge Wt, ib | | | Hole Depti | י | | |
| Total No. of Fragments: | | | Color: | | Yellow-t | rour |
| Cor TNT | | | Color. | | 16110#-0 | /I Own |
| For Subject HE | | | Principal Use | | Bombs | |
| 3 inch HE, M42A1 Projectile | , Lot_KC-5: | | 1 | | | |
| Density, gm/cc | 1.65 | 11** 1.65 | | | | |
| Charge Wt, Ib | 0.87 | 0.86 | | | | |
| Total No. of Fragments: | | | Material of Le | | Cast | |
| For TNT | 514 | 5₌՝ | Method of Le | odaing; | Cast | |
| For Subject HE | 609 | 659 | | | | |
| | | | Louding Dent | ilty: gm/cc | 1.65 | |
| Fragment Velocity: ft/sec At 9 ft | | | | | ······································ | |
| .^+ 25⅓ ft | | | Storage: | | | |
| Density, gm/cc | | | Method | | | |
| | | | Memod | | i | ry |
| Blast (Relative to TNT): | | | Hazard Cl | ass (Quantity | -Distance) (| class 9 |
| Air: | | | Compatibil | lity Group | G | roup I |
| Peak Pressure | | | į | | | |
| Impulse | | | Exudation | | | |
| Energy | | | | | | |
| Air, Confined: | | | Viscosity, | poises: | <u>I*</u> | II** |
| Impulse | | | Тетр, 83 | 3°C | 3.5 | 3.1 |
| | | | 95 | 60 0 | 3.5 2.6 | ž.7 |
| Under Water: Peak Pressure | | | Reference | :• | | |
| Impulse | | | References | · <u>·</u> | | |
| Energy | | | | | | nny Arsenel |
| | | | Technical Desensitiz | | RDX Compus | ition B, |
| Underground: | | | | • | | , |
| Peak Pressure | | | 1 | 3 | <u>5</u> | <u>6</u> |
| | | | 21)1 | 1313 | 1435 | 1750 |
| impulse | | | | | | |
| Impulse Energy | | | | 2053 | 1865 | |
| _ ' | dignated . | uses | | | | |
| Energy | | | | | | |

Compression C

| Composition: | Kelecular Weight: |
|--|--|
| RDX 88.3 | Oxygen Referee: CO ₂ % |
| Platicizer, non- | CO % |
| explosive 11.7* | Density: grn/cc |
| *Monexplosive oily plasticizer containing 0.6% lecithin. | |
| C/H Ratio | Freezing Point: 'C |
| Impact Sentitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ | Belling Petat: *C |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | Refrective Index, no |
| Friction Pendulum Test: | |
| Steel Since | Vecuum Stribi'ity Test: cc/40 Hrs, at |
| Fiber Shoe | 90°C |
| | 100°C 0.3 |
| Riffe Bullet Impiecr Test: Tricis | 120°C 0.7 |
| 5t-sim- | 135°C |
| Explains 0 Partials 0 | 150°C |
| Partials 0 Burned 0 | |
| Unaffected 100 | 200 Gram Bomb Sand Test: |
| Onorrected 100 | Sand, gin 46.5 |
| Explorion Temperature: *C | Sensitivity to Initiation: |
| Sizconds, 0.1 (no cop used) | Minimum Detonating Charge, gm |
| 5 72222222 295 | Mercury Fulminate |
| 5 Decomposes 285 | Leod Azide 0.25 |
| 10 | Tetryl 0.11 |
| 15 20 | Bellistic Morter, % TNT: (a) 120 |
| | Treuzi Test, % TNS: |
| 75°C International Heat Test: | Plate Dont Test: |
| % Loss in 48 Hrs | Method A |
| 180°C Heat Test: | Condition Hand Tamped |
| 96 Loss, 1st 48 Hrs 0.04 | Confined Yes |
| % Loss, 2nd 48 Hrs 0.00 | Density. gm/cc 1.58 |
| | Brisonco, % TNT 112 |
| Explosion in 100 Hrs None | · · · · · · · · · · · · · · · · · · · |
| Flummebility Index: | Detenation Rete: |
| | Confinement |
| Hygrescopicity: % 30°C, 95% RH 0.25 | Condition |
| | Charge Diameter, in. |
| Valuellity: 25°C, 5 days 0.00 | Density, gm/cc |

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Corposition C

| Fregmentellen Test: | Shaped Charge Effectiveness, THT = 100: (£) (g) |
|--|---|
| 90 mm HE, M71 Projectile, Let WC-91; Density, gm/cc | Glass Cones Steel Cones Hole Valume 113 114 |
| Charge Wt, Ib Tatel No. of Fragmants: | Hole Depth 101 11 |
| For ThiT For Subject HE | Colors White |
| 3 inch ME, M42A1 Projectific, Lnt KG-5: Deneity, gm/cc Charge Wt, Ib | Plastic demolition explosive |
| Total No. of Fragments: For TNT | Mathed of Leedings Hand tamped |
| For Subject HE | Leeding Density: gm/cc 1.49 |
| Programs Velocity: ft/sec At 9 ft At 25½ ft | Shureges |
| Deneity, gm/cz | Method Dry |
| Steat (Relative to TNT): | Hazard Class (Quantity-Distance) CLass 9 |
| Airs Peak Pressure Impulse Energy | Composibility Group Group I Exudation Exudes above 40°C |
| Air, Confined: Impulse Under Water: | Plasticity: Below O°C Brittle (0°C) 0-40°C Plastic Above 40°C Endes (40°C) |
| Peak Pressure Impulse | Above 40°C Emides (40°C) Paferences: |
| Energy Underground: Peak Pressure Impulse Energy | See references for Composition C-4. |
| | |

| Compeablen: | | Melecular Weigl. | |
|--|------|--|--|
| RDX 78.7 | | Oxygen Belence: | |
| THT 5.0 DMT 12.0 | | CO ₂ % CO % | |
| 12.0 1877 2.7 | | CO 70 | |
| NC 0.6 Solvent 1.0 | | Density: gm/cc | |
| SOLVERC 1.0 | | Molting Point: *C | |
| C/H Rotio | _ | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: | | Builing Point: *C | |
| Bureau of Mines Apparatus, cm 90 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | | Refrective Index, nº | |
| Fristian Pandulum Test: | | Vocuum Stability Test: | |
| Steel Shae Fiber Shae | | cc/40 Hrs, at | |
| FINAL SUID | | 90°C 2.0 | |
| Riffe Bullet Impact Test: Triols | | 4.0 | |
| % | | 120°C 9.0 | |
| Explosions 0 | | 135°C | |
| Partials 20 | | 130 C | |
| Burned 0 | | 200 Gram Bamb Sand Test: | |
| Unaffected 80 | | Sand, gm 47.5 | |
| Explosion Temperature: 'C | | Sensitivity to Initiation: | |
| Secreds, 0.1 (no cap used) | | Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 Decomposes 285 | | Lead Azide 0.25 | |
| 10 | | Tetryl 0.10 | |
| 15 20 | | Bellistic Morter, % TNT: (a) 126 | |
| | | Trough Toot, % TMT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | | Plate Dest Test: (c) Method B | |
| 100°C Heat Test: | | Condition Hand tamped | |
| % Loss, 1st 48 Hrs | 1.8 | Confined No | |
| % Loss, 2nd 48 Hrs | 1.4 | Density, gm/cc 1.52 | |
| Explosion in 100 Hrs | None | Brisance, % TNT 111 | |
| | | Outrocation Retay (A) | |
| Flommobility Index: | 178 | Detenation Rate: (d) Confinement None | |
| - | | Confinement None Condition Hand tamped | |
| Mygraecopicity: % 30°C, 95% RH | 0.55 | Charge Chameter, in. 2.0 | |
| | | Density, gm/kc 1.57 | |
| Veletility: 25°C, 5 days | 0.00 | 1.7/ | |

| regularitation Test: | Shaped Charge Effectiveness, TNT = 100: |
|---|---|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, lb | Glass Cones Steel Canes Hale Volume Hale Depth |
| Total No. of Fragments: For TNT | Color: White |
| For Subject HE | Principal Uses: Plastic demolition explosi |
| 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc | |
| Charge Wt, Ib | |
| Total No. of Fragments: For TNT For Subject HE | Method of Leading: Hand tamped |
| FOR Subject FIE | Locding Density: gm/cc 1.57 |
| regment Velocity: ft/sec At 9 ft At 25½ ft | Storage: |
| Density, gm/cc | Method Dry |
| lest (Relative to TNT) | Hozard Class (Quantity-Distance) Class 9 |
| Air: Peak Pressure Impulse Energy | Compotibility Group Group I Exudation Volatilizes above 52°C |
| Air, Confined: Impulse | Plasticity: Below O°C Plastic (-30°C) 0-40°C Plastic |
| Under Weter: Peak Pressure | above 40°C Hard (52°C)* |
| hpulse Vnergy | *Due to volitalization of plasticizer. References: |
| Undchreund: Peak Pressure | See references for Composition C-4. |
| Impulso Energy | : |
| d* | |
| | |
| | 1 |

| Compacition: | Molocutar Weight: |
|---|--|
| % | Oxyg. n Colonse: |
| RDX 77 | CO. A |
| Tetryl 3 | co % |
| INT 10 | |
| NET 5 | Density: gm/cc |
| ¥C 1 | Meltine Point: "C |
| C/H Ratio | Freezing Point: *C |
| Impact Seasitivity, 2 Kg Wt: | Bailing Paint: *C |
| Bureau of Mines Apparatus, cm 100+ | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 14 | Refrective Index, no |
| Picatinny Arsenal Apparatus, in. 14 Sample Wt, mg 33 | n <mark>o</mark> |
| 33 | n _{ac} |
| Friction Pendulum Test: | Vacuum Stability Test: |
| Steel Shoe Unaffected | cc/40 Hrs, at |
| Fiber Shoe Unaffected | 90°C |
| Ave. Bullet Inc a Cont Tit. | 100°C 1.21 |
| Rifle Bullet Impact Test: Trials | 120°C . 11+ |
| % Fundament | 135% |
| Explosions 0 | 150°C |
| Partials 40 | |
| Burned 0 | 2f 7 Grem Bomb Sand Test: |
| Unaffected 60 | Sand, gm 53.1 |
| Explosion Temperature: 'C | Sensitivity to Initiation: |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm |
| 1 | Mercury Fulminate |
| 5 Decomposes 280 | Lead Azide 0.20 |
| 10 15 | Tetryl 0.08 |
| 20 | Bellistic Morter, % THT: (a) 126 |
| 75°C International Host Test: | Trous Test, % TNT: (b) 117 |
| 73°C International Moor Foot: % Loss in 78 Hrs | Mote Dent Test: (c) |
| A month of the title | Method B |
| 100°C Heat Test: | Condition Hand tamped |
| | Confined No |
| | Density, gm/cc 1.57 |
| , | Brisance, % TNT 118 |
| Explosion in 100 Hrs None | |
| | Detenotion Rate: (d) |
| Elementille, index. | Confinement None |
| Flammobility Index: | |
| | Condition Hand tamped |
| | Condition Hand tamped Charge Diameter, in. 1.0 |
| Flammobility Index: Hygroscopicity: % 30°C, 95% RH 2.4 Volcatility: 25°C, 5 days 1.15 | Condition Hand tamped |

| regimentation Test: | | Shaped Charge Effectiveness, TNT = 100: |
|---------------------------------|-------------|--|
| 90 mm HE, M71 Projestile, Let | WC-91: | Glass Cones Stee! Cones |
| Density gm/cc | 158 | Hole Volume |
| Charge Wt, Ib | 2045 | Hole Depth |
| Total No. of Fragments: | | Color: Yellov |
| For TNT | 703 | terror. |
| rox Subject HE | 944 | Principal Vess: Plastic desolition emplosive |
| 3 inch HE, MASAT Projectile, Le | e KC-5: | Principal Uses: Plastic demolition explosive |
| Density, gm/cc | 1.60 | |
| Charge Wt, Ib | 0.842 | |
| Total No. of Fragments: | | |
| For TNT | 514 | Method of Looding: Hand tamped |
| For Subject HE | 671 | |
| . or ourgont 11% | | Leading Density: gm/cc 1.58 |
| regment Velocity: ft/soc | | `` |
| At 9 ft At 251/4 ft | | Street: |
| Density, gm/cc | | |
| Duraity, gm/sc | | Method Dry |
| lest (Relative to TNT): | | Hazard Class (Quuntity-Distance) Class 9 |
| Air: | | Compatibility Group Group I |
| Peak Pressure | 10 5 | |
| Impulse | 109 | Exudation Exudes at 77°C |
| Energy | 20, | |
| Ale Comitmed | | Plasticity: |
| Air, Confined: Impulse | | Below 0°C Hard (-29°c) |
| ···· p. 2 iu u | | Below 0°C Hard (-29°C) 0-40°C Plastic |
| Under Water: | | Above 40°C Exudes (77°C) |
| Peak Pressure | | |
| Impulse | | Booster Sensitivity Test: (h) |
| Energy | | Condition Pressed Tetryl. sm 160 |
| Underground: | | Tetryl, gm 100 Wax, in. for 50% Detonation 1.36 |
| Peak Pressure | | Density, gm/cc 1.62 |
| Impulse | | |
| Energy | | References: |
| , | | See references for Composition C-4. |
| | | |
| | | |
| | | |

| leuspealitions 96 | Meieculer Weight: |
|--|--------------------------------------|
| RIX 91 | Oxygen Selence: CO ₂ % |
| Plasticizer, non- explosive 9* | CO % Density: gm/cc |
| * Contains polyisobutylene 2.15; mod 1.65 and di(2-ethylhexyl) sebacat | or oil |
| C/H Ratio | Freezing Point: *C |
| mpost Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ | Beiling Point: 'C |
| Sample Wt 20 mg | Refractive Index, no |
| Picatinny Arsenal Apparatus, in. 19 Sample Wt, mg 27 | n _s |
| | n |
| Friction Pandulum Test: | Vocuum Stability Test: |
| Steel Shoe Unaffected | cc/40 Hrs, at |
| Firm Shoe Unaffected | 90°C |
| Riffe Bullet Impact Test: Trials | 100°C 0.26 |
| % | 120 C |
| Explosions 0 | 135°C |
| Purtials 0 | 150°C |
| Burned 20 | 200 Grem Bomb Send Test: |
| Unaffected 80 | Sand, gm 55.7 |
| Explosion Temperature: °C | Sensitivity to Initiation: |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm |
| 1 5 290 | Mercury Fulminate |
| 5 290 !0 | Lead Azide 0.20 |
| :0 15 | Tetryl 0.10 |
| 20 | Ballistic Mc:ter, % TNT: (a) 130 |
| | Treuzi Test, % TNT: |
| 75°C Interpolational Heat Test: % Loss in 48 Hrs | Plate Cent Test: (c) |
| , | /Method E |
| 100°C Here Test: | Condition Hand tamped |
| % Loss, At 48 Hrs 0.13 | |
| % Len, 2n1 48 Hrs 0.00 | |
| Explicion in 100 Hrs Rone | Brisance, % TNT 175 |
| The same of the sa | Detenation Rate: (d) |
| Flammability Index: | Confinement |
| Hygrescopicity: % 30°C, 95% RH N11 | Condition Hand temped |
| MII det in designation of the continuent of the | Charge Diameter, in. 1.0 |
| | Density, gm/cc 1.59 |

| Progmentation Yes* | Shoped Charge Effectives | ness, TNT = 100; | |
|--|---|---|--------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Gloss Co | ines Stret Cories | |
| Density, gm/cc | Hole Volume | | |
| Charge Wt, Ib | Hole Depth | | |
| ral Nr. of Fragments: | Celer: | Light brown | |
| For TNT | • | 776#4 010#4 | |
| For Subject HE | Principal Uses: Plastic | c demolition explosi | ve |
| 3 inch HE, M42A1 Projectile, Let KC-S: | | | |
| Density, gm/cc | | | |
| Charge Wt, Ib | | | |
| Total No. of Fragments: | Method of Looding: | *************************************** | |
| For TNT | manual or Locality: | Hand tamped | |
| For Subject HE | | | - , - , |
| | Leeding Density: gm/cc | 1.60 | |
| ingment Velocity: ft/sec At 9 ft | | | |
| At 251/2 ft | Storage: | | |
| Density, gm/cc | Methr d | Dry | |
| last (Relative to TNT): | Hazard Class (Quantity | -Distance) Class 9 | |
| Air: | Compatibility Group | Group I | |
| Peak Pressure | | 0 | |
| Impulse | Exudation | None at 77°C | |
| Energy | | - | |
| Air, Conflant: Impulse | Effect of Temperatur Rate of Detonation: | re on (i) | |
| Under Weter: | 16 hrs at, °C | -54 21 | |
| Peak Pressure | Density, gm/cc Rate, m/sec | 1.36 1.35 7020 7040 | |
| Impulse | | 1020 1040 | |
| Energy | Plasticity: | | |
| Underground: | Below 0°C | Plastic (-57°C |) |
| Peak Pressure | 0-40°C Above 40°C | Plastic Plastic (7.00) | |
| Impulse | | 1111010 (1, 0) | |
| Energy | | | |
| | | | |
| | i | | |
| | i | | |
| | İ | | |
| | | | |

Preparation:

In manufacturing Composition C-3, the mixed plasticizing agent is heated in a melting kettle at 100°C. Water-wet RDK is added and heating and stirring are continued until all the water is evaporated. This mixture is then cooled and hand pressed into demolition blocks or special item assumition.

Composition C-4 is prepared by hand kneeding and rolling, or in a Schreder Bowl mixer, RDX of 44 micron size or less with the polyisobutylene-plasticizer previously made up in ether. The thoroughly blended explosive is dried in air at 60°C and loosely packed by hand tamping to its maximum density.

Origin:

Developed by the British during World War II as a plastic explosive which could be hand shaped. It was standardized in the United States during World War II and subsequent development led to mixtures designated C-2, C-3 and C-4.

Destruction by Chemical Decomposition:

Composition C-3 is decomposed by adding it slowly to a solution composed of 1 1/4 parts sodium hydroxide, 11 parts vater, and 4 parts 95% alcohol, heated to 50°C. After addition of Composition C-3 is complete, the solution is heated to 80° C and maintained at this temperature for 15 minutes.

References: 11

- (a) Committee of Div 2 and 8, H To, Report on HMX and Tritonal, OSRO No. 5406, 31 July 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, GURD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-0RD-3723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, 18 September 1943, NIPC Contract W-672-ORD-5723.
- (h) L. C. Smit and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.

liSee footnote 1, page 10.

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Compositions C, r-2, C-3, C-4

- (i) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Temperatures, PATR No. 2303, November 1956.
 - (j) Also see the following Picatinny Arsenal Technical Reports on RDX Composition C:

| | <u>o</u> | <u>1</u> | 3 | 4 | 2 | <u>6</u> | I | <u>8</u> | 2 |
|-----------------|----------|----------|------|--------|--------------|----------------------|------|-----------------------|------|
| Comp C | 1260 | | 1293 | | | | | 1518 18 3 8 | |
| Comp C-2 | | 1611 | 1293 | O) Els | 3.505 | 1416 | 1000 | 1518 | |
| <u>case (2)</u> | | TOTT | 1713 | 2154 | 1595 1695 | 1416 1556 1766 | 1797 | 1518 2028 | |
| Comp Cal | | | | | 1885 | 1766 1766 | 1907 | 1838 | 1819 |
| | | | | | | | | 1958 | |

Copper Chlorotetrasole

| Composition: | Melecular Weight: (CuCgNgCl2) | 271 | | | |
|---|-------------------------------------|--------------|--|--|--|
| % C 8.9 N — N | Oxygen Belence: | | | | |
| (i) Sccr | CO, % | -30 -18 | | | |
| и 41.5 йи | | | | | |
| CI 26.2 K—N | Density: gm/cc | 2.04 | | | |
| Cu 23.4 H _ H | Melting Point: °C | | | | |
| C/H Ratio | Freezing Point: *C | | | | |
| Impect Sensitivity, 2 Kg Wt: Bureou of Mines Apporatus, cm | Beiling Point: 'C | | | | |
| Sample Wt 20 mg Picotinny Arsenal Apparatus, in: 1; (1 1b wt) 3 Sample Wt, mg 9 | Refrective Index, ng. ng. ng. | | | | |
| Friction Pendulum Test: | Vecuum Stability Test: | | | | |
| Steel Shoe Exploded | cc/40 Hrs, at | | | | |
| Fiber Shoe Exploded | 90°C | | | | |
| Rifle Sullet Impact Test: Triols | 100°C | | | | |
| % | 120°C 135°C | | | | |
| Explosions | 150°C | | | | |
| Partials | | | | | |
| Burned | 200 Gram Bomb Sand Tost: (f) | 05.0 | | | |
| Unaffected | Sond, gm Black powder fuse 27.4 | 25:3 17:0 | | | |
| Explosion Temperature: °C | Sensitivity to Initiation: | | | | |
| Seconds, 0.1 (nu cop used) | Minimum Detonating Charge, gm | | | | |
| 1 5 305 | Mercury Fulminate Lead Azide 0.20 | 0.30 | | | |
| 10 | Lead Azide 0.20 Tetryl 0.10 | 0.30 | | | |
| 15 | | | | | |
| 20 | Bellistic Morter, % TNT: | | | | |
| 75°C International Host Test: | Trouzi Test, % TNT: | | | | |
| % Loss in 48 Hrs | Piete Dent Test: Method | | | | |
| 00°C Heat Test: | Condition | | | | |
| % Loss, 1st 48 Hrs 2-67 | Confined | | | | |
| % Loss, 2nd 48 Hrs 0-10 | Density, gm/cc | | | | |
| Explosion in 100 Hrs None | Brisance, % TNT | | | | |
| Flommability Index: | Dutonation Rate: Confinement | | | | |
| | Condition | | | | |
| Hygroscopicity: % 30°C, 90% RR 3.11 | Charge Diameter, in. | | | | |
| Walastita | Density, gm/cc | | | | |
| Volatility: | Rate, meters/second | | | | |

Copper Chlorotetrasole

| regmentation Test: | Skaped Cherye Effectiveness, TNT : | ± 100: | | |
|--|--|-----------------|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Ste | ol Cones | | |
| Density, gm/cc | Hole Volume | | | |
| Charge Wt, Ib | Hole Depth | <i>i</i> | | |
| Tetal No. of Fragments: | Colors | lee | | |
| For TNT | | T | | |
| For Subject HE | Principal Uses: Primary explosive | | | |
| 3 inch HE, M42A1 Projectile, Let KC-S: | | | | |
| Density, gm/cc | l | | | |
| Charge Wt, Ib | | · · | | |
| Total No. of Fragments: | Method of Leading: Pressed | | | |
| For TNT | | | | |
| For Subject HE | Leading Density: gm/cc psi x 10 ³ (c) | | | |
| regment Velocity: ft/sec | 10 20 40 1.49 1.63 1.74 | 70 1.86 | | |
| At 9 ft At 251/ ₆ ft | Storogn: | | | |
| Density, gm/cc | Method | Wet | | |
| lest (Relative to TNT): | Hazard Class (Quantity-Divisions) | Ciass 9 | | |
| Aire | Compatibility Gray | Group M | | |
| Peak Pressure | 6. 4.N | | | |
| Impulse | Exudation | None | | |
| Energy | | | | |
| Air, Confined: | Stab Sensitivity: | (e) | | |
| Impulse | Density Firing Point (in | ich-ounces) | | |
| | <u>ga/cc 05 505</u> | 1005 | | |
| Under Weter: Peak Pressure | 1.49 9 11 | 15 | | |
| | 1.63 8.5 10 | 12 | | |
| tmpuis. Energy | 1.74 6 | - 9 6 | | |
| धक्काश्चर | 1.86 | 6 | | |
| Underground: Pack Preseure | Heat of: | | | |
| Impulse | Explosion, cal/gm | 432 | | |
| Energy | Specific Heat, cal/gm/°C | | | |
| | Temp range C ^O -3C ^O C Wt of *emple, go | 0.155 0.8910 | | |
| | | | | |

Properation: (a)

Five grams of 5-aminotetrasole are dissolved in a mixture of 200 ml of water and 70 ml of concentrated BCL. Prough heroseme or nujol (which gives a slightly cleaner product) is added to provide a layer of oil approximately $1/h^{\rm m}$ thick on the surface. With only moderate stirring and external cooling to 10^{0} - 15° C, a solution of 5 grams of sodium nitrite in 70 cc of water is added rapidly by means of a burette extending below the oil layer. Immediately after this addition, a solution of 5 grams of cupric chloride in a minimum amount of water is added all at once, and stirring is continue, for about I hour. The reading is allowed to stand for a few minutes till the bright blue copper salt separates. The oil is removed by decantation and may be reused. The salt is filtered; washed with water alcohol, and either; and dried - giving a yield of 6 grams or 7h%.

Origin:

3,46

The copper salt of 5-chlorotetrazole was first described in 1929 by R. Stolle (with E. Schick, F. Henke-Stark and L. Krauss) who prepared the compound by reaction of the diazonium chloride of 5-aminotetrazole with copper chloride (Ber 62A, 1123).

References: 12

- (a) R. J. Gaughran and J. V. R. Kaufman, Synthesis and Properties of Halotetrazole Salts, PATR No. 2136, February 1955.
- (b) A. M. Anzalone, J. E. Abel and A. C. Forsyth, Characteristics of Explosive Substances, for Application in Assumition, PATR No. 2179, May 1955.
- (c) A. C. Forsyth, Pfc, S. Krasner and R. J. Gaughran, Development of Optimus Explosive Trains. An Investigation Concerning Stab Sensitivity versus Loading Density of Some Initiating Companies, PATR No. 2146, February 1955.

¹²See foutnote 1, page 10.

Cyanuric Triazide

| Composition: | Molecular Weight: (C3N12) 204 |
|--|---|
| c 17.6 N ₂ | Oxygen Belence: |
| 13 | CO ₂ % -47.1 CO % -23.5 |
| и 82.4 | |
| и | Jensity: gm/cc Crystal 1.54 |
| ng-c c-ng | Molting Point: °C 94 |
| C/H Ratio | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apparotus, cm 1 kg vt 7 | Builing Faint: 'C |
| Sample Wt 20 mg | Refrective Index, no |
| Picatinny Arsenal Apparatus, in | n _m |
| Sample Wt, mg - | n <u>o</u> |
| Friction Pandulum Test: | · |
| Steel Shoe | Vocuum Stebility Test: cc/40 Hrs, at |
| Fiber Shoe | 90°C |
| | 100°C |
| Riffle Bullet Impact Test: Trials | 120°C |
| % European | 125°C |
| Explosions Partials | 150°C |
| Burned | 200 Grem Bomb Sond Test: |
| Unaffected | Sand, gm 32.2 |
| | |
| Explacion Temperature: *C Seconds, 0.1 (no cop used) 252 | Sensitivity to Initiation: Minimum Detonating Charge, gm |
| 1 | Mercury Fulminate - |
| 5 | Lead Azide 0-20 |
| 10 | Tetryi 0.10 |
| 15 | |
| 20 | Bellistic Morter, % TNT: |
| | Trouzi Test, % TNT: |
| 75°C International Heat Tast: % Loss in 48 Hrs | Plate Dest Test: Method |
| | Condition |
| 100°C Heat Test: | Confined |
| % Loss, 1st 48 idrs | Density, gm/cc |
| % Loss, 2nd 48 Hrs. | Brisance, % TNT |
| Explosion in 100 Hrs | |
| Flammability Index: | Detenation Rate: Confinement |
| | Condition - |
| Hygrescepicity: % | Charge Diameter, in. 0-3 |
| | Density, gm/cc 1-15 |
| Voistility: Decomposes above 100°C | Rate, meters/second 5550-5600 |

Cyanuric Triazide

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: |
|---|---|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hole Volume Hole Depth |
| Total No. of Fragments: For TNT For Subject HE | Colorless |
| 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principed Uses: Not used because of difficulty in controlling sensitivity. |
| Total No. of Fragments: For TNT For Subject HE | Method of Looding: Pressed |
| Fragment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc | Leeding Density: gm/cc At 200 atmospheres 1.4 At 800 atmospheres 1.5 Storage: |
| West (Reintive to TNT): | Method Hozard Class (Quantity-Distance) Class 9 |
| Air: Peak Pressure Impulse Energy | Compatibility Group Exudation None |
| Air, Confined: Impulse | |
| Under Weter: Peak Pressure Impulse Energy | |
| Underground: Peak Pressure Impulse | |
| Energy | |
| | |

Preparation:

By the reaction of cyanuric chloride with an aqueous solution of sodium aside:

Recrystallization should be avoided as it leads to very large crystals which explode when broken.

Origin:

Cyanuric Triszide was prepared in 1847 by Cahours from chlorine and methyl cyanate. Later James improved the process (JCS 51, 268 (1887) and in 1921 E. Ott patented the preparation from cyanuric chloride and sodium axide (Ref b) Taylor and Rinkenbach prepared cyanuric triszide in a pure state and determined its properties (Ref c).

Initiating Efficiency:

Reported to be more efficient than lead axide. Capable of initiating Explosive D.

Solubility:

Insoluble in water; readily soluble in hot ethanol, acetone, benzene, and ether.

Heat of:

Formation, cal/gm

-1090 to -1138

References: 13

- (a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
 - (b) Ott and Ohse, Ber 54, 179 (1921).
 - (c) Taylor and Rinkenbach, Bureau of Mines, RI 2513 (1923). Taylor and Rinkenbach, J Frank Inst 204, 369 (1927).

¹³See footnote 1, page 10.

| Composition: | | Meloculor Weight: (C3H6N6O6) | 555 |
|--|------|---------------------------------------|--|
| C 16.3 02N-N N-N | 100 | Oxygen Balance: | |
| - | 2 | CO ₂ % | 0.0 -22 |
| H 2.7 H ₂ ¢ CH ₂ | | CO 18 | |
| и 37.8 | | Density: gm/cc Crystal | 1.82 |
| 0 43.2 NO ₂ | | Melting Point: *C | 204 |
| C/H Ratio 0.095 | | Freezing Point: "C | |
| impact Sanshivity, 3 Kg Wt: | 20 | Beiling Point: *C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | 32 | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. | 8 | nº | |
| Somple Wt, mg | 18 | · · · · · · · · · · · · · · · · · · · | |
| | | n <u>s</u> | |
| Frietion Pendulum Test: | | Vacuum Stability Test: | |
| Steel Shoe Explode | | cc/40 Hrs, at 90°C | |
| Fiber Shoe Unaffec | tel | 100°C | 0.7 |
| Riffe Buffet Impact Test: Trials | | 120°C | 0.9 |
| % | | 135°C | - |
| Explosions 100 | | 150°C | 2.5 |
| Portials 0 | | | |
| Burned 0 | | 200 Gram Bomb Sond Yest: | (0.0 |
| Unaffected 0 | | Sand, gm | 60.5 |
| Explosion Temperature: *C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) 405 | | Minimum Detonating Charge, gm | |
| 1 316 | | Mercury Fulminate | 0.19 [®] |
| 5 Decomposes 260 | | Lead Azide | 0.05* |
| 10 240 | | Tetryl * Alternative initiating char | - Fes. |
| 15 235 20 - | | Bollistic Morter, % TNT: (a) | 150 |
| | | Trousi Test, % TNT: (b) | 157 |
| 75°C International Heat Test: | 0.00 | Plate Dent Test: (c) | ······································ |
| % Loss in 48 Hrs | 0.03 | Method | A |
| 100°C Heat Test: | | Condition | Pressed |
| % Loss, 1st 48 Hrs | 0 04 | Confined | Yes |
| % Loss, 2nd 48 Hrs | 0.00 | Density, gm/cc | 1.50 |
| Explosion in 100 Hrs | None | Prisonce, % TNT | 1 3 5 |
| | | Detenation Rate: | |
| Flammability Index: (d) | 278 | Confinement | None |
| | | Condition | Pressed |
| Hygrescopicity: % 25°C, 100% RH | 0.02 | Charge Diameter, in. | 1.0 |
| | | Density, gm/cc | 1.65 |
| Veletility: | Nil | Density, grit/CC | 1.0) |

^{*}Name given by Clarence J. Bain of Picatinny Arsenal. Germans call it Hexogen; Italians call it T4; British, RDX.

Cyclonite (RDK)

| Secretar Scholistiny Yest: | Decemposition Equation: (1) Oxygen, atoms/sec 10 ¹⁸ .5 |
|---|---|
| Condition | Oxygen, atoms/sec 10 ¹⁰⁺³ |
| Tetryi, gm | Heat, kilocolorie/mole 47.5 |
| Wax, in. for 50% Detonation | (AH, kcat/mol) |
| Wax, gm | Temperature Range, *C 213-299 Phase Idout d |
| Density, gm/cc | Phase Liquid |
| Next of: Combustion, col/gm 2285 | Armor Plate Impact Test: |
| Explosion, cel/gm 1280 | |
| Gas Volume, cc/gm 908 | 60 mm Merter Projectile: 50 % Inert, Velocity, ft/sec |
| Formation, cal/gm -\$5 | Aluminum Fineness |
| Solution, cal/mol (28-55% HN) ₂) 7.169 | |
| Assuming cyclonite unimolecular | 500-16 Genarel Purpose Bombs: |
| Specific heat: col/gm/*C | Plate Thickness, inches |
| <u>°c</u> | Trace Principals, market |
| 20 0.298 100 0.406 | 1 |
| 40 0.331 120 0.427 | 11/4 |
| 60 0.360 140 0.446 80 0.384 | 11/2 |
| | 13/4 |
| Burning Rate: | |
| cm/sec | Somb Drop Test: |
| Thermal Conductivity: (h) | |
| col/sec/cm/°C 1.263 6.91 x 10 1 Density, gm/cc 1.533 6.98 x 10 | 177, 2000-ib Semi-Armer-Piercing Bemb vs Concrete: |
| Coefficient of Expension: | Max Safe Drop, ft |
| Linear, %/°C | 500-lb General Purpose Bomb vs Concrete: |
| No W 400 | No. |
| Volume, %/*C | Height, ft |
| Hardness, Mohe' Scale: 2.5 | Trials |
| | Unaffected |
| Young's Medulus: | Low Order |
| E', dynes/cm² | High Order |
| E, Ib/inch ² | 1000-th General Purpose Somb vs Concrete: |
| Density, gm/cc | 1500 to Gamera 1 arport from 15 constitute |
| | Height, ft |
| Coopposalve Strength: Ib/inch ² | Trials |
| - - | Unaffected |
| | |
| Vagar (resource: | Low Order |

Cyclonite (RDK)

| regmentation Test: | Shaped Charge Effectiveness, TNT = 100: |
|--|--|
| 90 man HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones |
| Density, gm/cc | Hole Volume |
| Charge Wt, Ib | Hole Depth |
| Total No. of Progments: | Color: White |
| For TNT | will of |
| For Subject HE | Blacked Here Petersten have shown and |
| De-C MR AARRAS Districts Line MR Di | Principal Uses: Detonator base charge, and ingredient for projectile and |
| 3 inch HE, M42A1 Projectile, Let KC-5: | bomb fillers |
| Density, grn/cc | |
| Charge Wt, Ib | |
| Total No. of Fragments: | Method of Leading: Pressed |
| For TNT | wanted & creamily. |
| For Subject HE | |
| | Leeding Dunnity: gm/cc pai x 10 ³ 5 10 12 15 2 |
| Fragment Velocity: ft/sec | 3 5 10 12 15 2 1.46 1.52 1.60 1.63 1.65 1.6 |
| At 9 ft | Storage: |
| At 251/4 ft | Sauce. |
| Density, gm/cc | Method Wet |
| Heat (Relative to TNT): | Hazard Class (Quantity-Distance) Class 9 |
| A1 | Corncatibility Group Group M (vet) |
| Air: Pack Pressure | Group L (dry) |
| Impulse | Exudation None |
| Energy | |
| | Effect of Temperature on |
| Air, Confined: Impulse | Rate of Detonation: (k) |
| m pane | 16 hrs at, °C -54 21 |
| Under Water: | Density, gm/cc 1.61 1.62 |
| Peak Pressure | Rate, m/sec 8100 8050 |
| Impulse | Effect of Temperature on |
| Energy | Impact Sensitivity: |
| Underground: | Temp. PA Impect Test |
| Peak Pressure | OC 2Kg Wt, inches |
| Impulse | Room 9 |
| Energy | 32.2 |
| | 104 5 |
| | |
| | |
| | |

Cyclonite (RDX)

| Solubility of Cycl | onite; gm/100 gr | of the follow | ing substances | <u>ı:</u> (j) |
|---|---|--|--|---|
| Nater | Alcohol | Acetone | Benzene | Tolueno |
| 90 0.005 90 0.025 70 0.075 90 0.19 100 0.28 | 0 0.040 20 0.105 40 0.240 60 0.579 78 1.195 | 0 4.4 20 7.3 40 11.5 60 18. | © | 0 0.015 20 0.02 40 0.05 60 0.13 80 0.30 100 0.65 |
| Ethyl acetate | tetrachloride | Methanol | Ether | THT |
| 28 2.9 94 18. | °c <u>≰</u> 50 0.005 60 0.007 70 0.009 | oc ≰ 0 0.14 20 0.23 40 0.47 50 1.1 | 0c <u>\$</u> 10 0.05 20 0.056 30 0.076 | 80 4.4 85 5.0 90 5.55 95 6.2 100 7.0 |
| lsoamyl alsohol | Methyl acetate | -Ethoxyethyl acetate | Chlorobenzene | Trichloro- ethylene |
| °C | oc ≰ 20 2.9 30 3.3 40 4.1 50 5.6 | 00 4 20 0.15 30 0.16 40 0.19 50 0.25 | °C | 00 ± 0.20 0.20 0.22 40 0.24 50 0.26 |
| Tetra- chloroethane | Isopro- panol | Isobutanol | Chloroform | Mesityloxide |
| o _C | °C 4 38 0.18 | °c 4 | °C | °C ≰ 27 3.2 97 12.2 |
| Cyclo- hexanone | <u> Hi tro-</u> benzene | Mitro- ethene | Cyclo- pentanone | Acetonitrile |
| 0 _C <u>1</u> 12.7 97 25 | oc 4 25 1.5 97 12.4 | oc 4 28 3.6 93 19 | o _C ≰ 28 11.5 90 37 | °c ≰ 28 11 82 33 |
| | Methyl | ethyl ketone | | |
| | °c 28 | \$ 5.6 | | |

Cyclonite (RDX)

Solubility of Cyclonite, Holston Lot E-2-5 in Various Solvents:

Solubility gm/100 gm Solvent

| Solvent | Point, | Grade or Source | 28°0 | Heated | Crystalline Form |
|------------------------|-------------|---------------------|------|----------------|-------------------------|
| Acetone | 56 | CIP CIP | 8.2 | 16.5 at 60°C | hexagonal-thick |
| Cyclobess:none | 155.6 | CP CP | 13.0 | 24.0 at 9300 | cubic (massive form) |
| Mi trome thane | 100.8 | | Ĭ.5 | 12.4 at 97°C | plates |
| Acetonitrile | 81.6 | Miacet Chem. Co. | 11.3 | 33.4 at 93°C | plates |
| 1-Mitropropane | 126.5 | EK Pract | 1.4 | 10.6 at 93°C | abant |
| 2-Mitropropane | 120. | EK Prac: | 2.3 | 11.6 at 93°C | short needles |
| 2,4-Pentanedione | 140.5 | Carbide & | 2.9 | | short needles |
| | 140.9 | Carbon | 2.9 | 18.3 at 93°C | flat prises |
| Methylisobutylketone | 115.8 | | 2.4 | 9.6 at 93°C | long prisms |
| n-Propylacetate | 101.6 | EK Red Label | 1.5 | 6.0 at 93°C | long prisms, some cubic |
| n-Butylformte | 105.6 | EK Red Label | 1.4 | 4.6 at 93°C | long prisms |
| Ethyl acetate | 77.1 | Baker's P | 2.0 | 6.1 at boil. | hexagonal plates |
| n-Propylpropionate | 121 | EK Red Label | 0.8 | 1.6 at 93°C | short prisms, some |
| Butylacetate | 126.5 | El Technical | 1.1 | 4.0 at 93°C | long prisms |
| Methylethylketone | 79.6 | | 5.6 | 13.9 at boil. | coarse plates |
| Mitroethane | 114.2 | EK Red Label | 3.6 | 19.5 at 93°C | plates |
| Isopropylacetate | 88-90 | CIP | 1.1 | 3.2 at boil. | long prisms |
| Mesityloxide | 128 | EX Red Tabel | 4.8 | 14.5 at 93°C | plates |
| n-Amylacetate | 146 | CIP . | 1.0 | 2.1 at 93°C | prisms |
| Dimethylcarbonate | 88-91 | EX Red Label | 1.4 | 6.6 at boil. | plates |
| Diethylcarbonate | 125-126.5 | EK Red Label | 0.7 | 3.2 at 93°C | prisms |
| Isonmylacetate | 132 | CIP | 1.2 | 3.6 at 93°C | prisms |
| Ethylpropionate | 98-100 | EK Red Label | 3.0 | 10.7 at 93°C | fairly thick hex |
| Methyl-n-butyrata | 101.5-103.5 | EK Red Label | 1.2 | 4.9 at 93°C | plates needles |
| Cyclopentanone | 130.6 | EK Red Label | 11.5 | 39.0 at 93.500 | |
| Acrylonitrile | 77.3 | Cyanamid Cc. | 4.0 | 16.4 at boil. | flat plates |
| Methylcellosolveacetat | | Carbide & | 1.6 | 8.8 at 93°C | massive hexagons and |
| - | • | Carbon | | 212 22 75 0 | prisms |

^{*} EK, Eastman Kodak; Pract, practical.

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)

Ammonium nitrate and acetic anhydride are placed in a flask and, while the mixture is stirred at 75°C, the following three liquids are introduced concurrently and proportionately: acetic anhydride, concentrated nitric acid, and a solution of hexamine in glacial acetic acid. The final mixture is held for a short time at 75°C, diluted with water to 30% acetic acid, and simmered to hydrolyze unstable reaction by-products, which are a mixture of various nitrated and acetylated derivatives of hexamine fragments. After simmering, the slurry is cooled and the precipitated cyclonite removed by filtration. The yield is 78% of the theoretical amount (2 moles) of cyclonite melting at 199°C. By dissolving the ammonium nitrate in the nitric acid, a continuous process, based on 3 liquids, is possible.

The product is recrystallized from acetone, or cyclohexanone, to (a) remove acidity, (b) control particle size and (c) to produce stable \$\int_{\text{-HMX}}\$. The preparative procedure described above, the Bachmann or Combination process, yields cyclonite containing 3-84 HMX.

Origin:

First prepared by Henning in 1899 (German Patent 104,280) and later by von Hertz (U. S. Patent 1, 402,693) in 1922 who recognized its value as an explosive. Not used on a large scale in explosive ammunition until World War II.

Destruction by Chemical Decomposition:

Cyclonite (RDX) is decomposed by adding it slowly to 25 times its weight of boiling 5% sodium bydroxide. Boiling should be continued for one-half hour.

References: 14

- (a) I. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) Ph. Haoum, Z. ges Schiese Sprengstoffe, pp. 181, 229, 267 (27 June 1932).
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.

¹⁶ See footnote 1, page 10.

Cyclonite (RDX)

- (e) Argument Research Department (Woolwich), Solubility of RDK in Nitric Acid (ARD Expl Rpt 322/43 September 1943).
 - (f) Report AC-2587.
 - (g) <u>International Critical Tables</u> Land. Bornat.
- B. T. Fedoroff et al, A Manual for Explosives Laboratories, Lefax Society Inc, Philadelphia, 1943-6.
- (h) E. Rutchinson, The Therrel Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2001, First Report, August 1942.
- (i) R. J. Finkelstein and G. Gemow, Theory of the Detonation Process, NAVORD Report No. 90-46, 20 April 1947.
 - (j) <u>International Critical Tables</u>.
- (k) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
 - (1) Also see the following Picatinny Arsenal Technical Reports on Cyclonite:

| <u>o</u> | <u>1</u> | <u>2</u> | 3 | <u>4</u> . | 2 | <u>6</u> | I | 8 | 2 |
|--|--|---|---|--|--|--|---|--|---|
| 1170 1290 1360 1450 1760 1980 2100 | 1211 1241 1311 1421 1481 1561 1651 1741 1751 1761 2131 2151 | 582 1342 1352 1372 1402 1452 1492 1532 2062 2112 | 863 1193 1293 1433 1483 1503 1503 1713 1793 1923 | 1184 1414 1634 2024 2154 2204 | 65 1175 1185 1435 1445 1715 1855 1885 1915 1935 2095 2125 2205 | 1236 1316 1416 1446 1466 1476 1556 1756 1756 1796 1836 1936 1936 2056 2176 | 857 1207 1427 1437 1517 1617 1687 1737 1787 1787 1797 1957 2147 2227 | 1436 1458 1498 1578 1838 1958 2008 2028 2178 2198 | 709 1379 1429 1449 1469 1709 2059 2179 |

75

Cyclotol, 75/25

| Composition: | Melecular Weight: 224 | |
|--|---|--|
| % 75 | Oxygen Belance: | |
| RDX 75 | CO, % -35 CO % - 6 | |
| TNT: 25 | Dennity: gm/cc Cast 1.71 | |
| | Moliting Palet: *C | |
| C/H Rotio | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | Bohing Peint: *C | |
| Sample Wt 20 mg | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. Sample Wt, mg | n _m | |
| | n | |
| Frictive Pendulum Test: | Vocuum Stability Test: | |
| 5 eel Shoe Unaffected | cc/40 Hrs, at | |
| Fiber Shoe Unaffected | 90°C 100°C 2.23 | |
| Rifle Bullet Impact Test: Trials | 120°C 0.11 | |
| % | 135°C - | |
| Explosions 30 | 150°C - | |
| Partials Smokes 40 | | |
| Burned 0 Unaffected 30 | 200 Grem Bomb Sand Test: Sand, gre | |
| | | |
| Explosion Temperature: °C | Sensitirity to Initiation: Minimum Detonating Charge, gm | |
| Seconds, 0.1 (no unp used) | Mercury Fulminate | |
| 5 | Lead Azide | |
| 10 | Tetryl | |
| 15 | Ballistic Marter, % TNT: | |
| 20 | Transl Test, % TNT: | |
| 75°C International Heat Test: | Plate Deat Test: | |
| % Loss in 48 Hrs | Method | |
| 100°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs | Confined | |
| % Loss, 2nd 48 Hrs | Density, gm/cs | |
| Explosion in 100 Hrs | Brisance, % TNT | |
| | Confinement None None | |
| Floremobility Index: | Continerrant with white | |
| Floremability Index: | | |
| Floremobility Index: Hygroscopicity: % | Condition Cast Cast | |
| | | |

Cyclotol, 75/25

| Receiver Sensitivity Test: Condition | Decemposition Equation: _Oxygen, atoms/sec |
|--|--|
| Tetryl, gm | (Z/sec) |
| | Heat, kilocalarie/male |
| Wax, in. for 50% Detanation | (ΔH, kcal/mol) |
| Wax, gm | Temperature Range, °C |
| Density, gm/cc | Phase |
| Heat of: | Armor Plate Impact Test: |
| Combustion, col/gm 2625* | The state of the s |
| Explosion, cal/gm 1225* | 60 mm Mortor Projectile: |
| Gas Volume, cc/gm 862 | 50% Inert, Velocity, ft/sec |
| Formation, cel/gm | Aluminum Fineness |
| Fusion, col/gm (h) 5.0 | |
| *Calculated from composition of mixture. | 500-lb General Purpose Sembs: |
| Specific Heat: cal/gm/°C (h) | |
| <u>°c</u> | Plate Thickness, inches |
| -75 0-220 75 0.352 | 1 |
| 0 0.225 85 0.325 | |
| 25 0.25¼ 90 0.33½ | 11/4 |
| 50 0.296 100 0.351 | 1½ |
| Burning Rate: | 1¾ |
| cm/sec | |
| | Bomb Drop Test: |
| Thormal Conductivity: | |
| cal/sec/cm/°C | 17, 2000-th Semi-Armer-Piercing Bemb vs Concrete: |
| Coefficient of Expension: | Max Safe Drop, ft |
| Linear, %/°C | 500-lb General Purpose Bomb vs Concrete: |
| Volume, %/°C | |
| | Height, ft |
| Hardness, Mahs' Scale: | Trials |
| | Unaffected |
| Young's Moduler: | Low Order |
| E', dynes/cm² | High Order |
| E, lb/inch ^a | 1000 B. Connect Burner B. A. G. |
| Density, gm/cc | 1000-lb General Purpose Somb vs Concrete: |
| | Height, ft |
| Compressive Strongth: lb/inch² | Trials |
| | Unoffected |
| Vapor Pressure: | Low Order |
| *C mm Mercury | High Order |
| | |
| | |
| | |
| | |
| | |

Cyclotol, 75/25

| Fragmentation Test: | | Shaped Charge Effectiveness, TMT = | 100: |
|--------------------------------------|--------------|--|------------------|
| 90 mm HE, M71 Projectile, L | of WC-91: | Glass Cones Steel | Cones |
| Density, gm/cc | 1.72 | Hole Volume | |
| Charge Wt, tb | 5.55 | Hole Depth | |
| Total No. of Fragments: | | Color: Yallin huge | |
| For TNT | 703 | Yellow-buff | |
| For Subject HE | 1514 | Principal Utas: Shaped charge b | omb especially |
| 3 inch HE, M42A1 Projectile, | Let KC-5: | fragmentation; grenades | |
| Density, gm/cc | | grenades | • |
| Charge Wt, Ib | | · | |
| Total No. of Fragments: | | Method of Looding: | Cast |
| For TNT For Subject HE | | | • |
| | | Leading Density: gm/cc | 1.71 |
| Fragment Velocity: ft/sec At 9 ft | | | |
| At 251/2 ft | | Storogo: | |
| Density, gm/cc | | Method | Dry |
| Blast (Relative to TNT): | (d) | Hazard Class (Quantity-Distance) | Class 9 |
| Air: | | Compatibility Group | Group I |
| Peak Priss /re | 111 | | |
| Impuise | 126 . | Erudation | |
| Energy | | Preparation: See Composition B | |
| Air, Confined: | | | |
| 1mpulse | | Origin: Developed by the Briti Wars I and II and standardi States early in World War I | zed in the Unite |
| Under Weter: Peak Pressure | | Black Modulus at Room Temperature (25°-30°C): | |
| Impulse Energy | • | Dynes/cm ² x 10-10 Density, gm/cc | 3.09 1.74 |
| Underground: | | Absolute Viscosity, poises:* Temp, 85°C | • |
| Peak Pressure Impuis | | 90°C | 210** |
| _ ' | | Efflux Viscosity, Saybolt Seco | nds: |
| Energy | | Тетр, 85°С | 9-14 |
| | | * Compositions using Spec Grade Class A RDX. ** Composition prepared using Riparticle size. | |

Cyclotol, 70/30

| Composition: | Melecular Weight: | 224 |
|---|--|-------------|
| RDX 70 | Oxygen Belence: | |
| 10 | CO. % | -37 |
| INT 30 | CO % | - 8 |
| | Density: gm/cc Cast | 1.71 |
| | Melting Point: 'C | |
| C/H Ratio | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apparotus. cm 60 | Boiling Point: *C | |
| Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. 14 | <u> </u> | |
| Sample Wt, mg 20 | n _B | |
| · | n ₃₆ | |
| Friction Pondulum Test: | Vocuum Stability Test: | |
| Steel Shoe Unaffected | cc/40 Hrs, at | |
| Fiber Shoe Unaffected | 90°C | |
| Riffe Bullet Impact Yest: Triols | 100°C | |
| · | 120°C | 0.86 |
| % Explosions 30 | 135°C | |
| Partials 30 | 150°C | |
| Burned 0 | 200 Grem Bemb Send Test: | |
| Unaffected 40 | Sand, gm | 56.6 |
| P. Mata. B. | | 75.0 |
| Explosion Temperature: *C Seconds, 0.1 (no cap used) - | Sensitivity to Initiation: Minimum Detonating Charge, g | <u></u> |
| 1 - | Mercury Fulminate | 0.21* |
| 5 Decomposes 265 | Lead Azide | 0.20* |
| 10 | | 0.20* |
| 15 | Tetryl *Alternative initiating char | rges. |
| 20 | Ballistic Morter, % TNT: (a) | 135 |
| | Trenzi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: (b) | _ |
| | Method | В |
| 100°C Heet Test: | Condition | Cast |
| % Loss, 1st 48 Hrs 0-07 | Confined | No |
| % Loss, 2nd 48 Hrs 0.08 | Density, gm/cc | 1.725 |
| Explosion in 100 Hrs None | Brisance, % TNT | 136 |
| | Detonation Rate: | |
| Flammability Index: | Confinement | None |
| | Condition | Cast |
| | | |
| Hygrescopicity: % N11 | Charge Diameter, in. | 1.0 |
| Hygroscopicity: % N11 Volatility: N11 | Charge Diameter, in. Density, gm/cc | 1.0 1.73 |

Cyclotol, 70/30

| regmentation Test: | | Shaped Charge Effectiveness, TNT = | : 1 00 2 |
|--------------------------------|------------|--|-----------------|
| 90 mm HE, MJ: Projectile, La | WC-91: | Gloss Cones Stee | il Cones (e) |
| Density, gm/cc | 1.71 | Hole Volume | |
| Charge Wt, Ib | 2.213 | Hole Depth | 130 |
| Total No. of Fragments: | | Color: Y | ellow-buff |
| For TNT | 703 | Come: | E(10W-0011 |
| For Subject HE | 1165 | | |
| 3 inch HE, M42A1 Projectile, L | as KC.S. | Principal Uses: Shaped charge be especially frag | |
| Density, gm/cc | 1.72 | projectiles, gr | enades |
| **** | 0.923 | | |
| Charge Wt, It | 0.55 | | |
| Total No. of Fragments: | | Method of Leading: | CABL |
| For TNT | 514 | | |
| For Subject HE | 828 | | |
| | | Loading Density: gm/cc | 1.71 |
| regment Velocity: ft/sec | | | |
| At 9 ft At 251/2 ft | | -Storage: | |
| Density, gm/cc | | | |
| Serienty, Willy Co. | | Method | Dry |
| liest (Relative to TNT): | (d) | Hazord Class (Quantity-Distance) | Class 9 |
| | \ , | | |
| Air: | | Compatibility Group | Group I |
| Peak Pressure | 110 | | |
| Impulse | 120 | Exudation | |
| Energy | | | |
| Air, Confired: | | Preparation: See Composition | В |
| Impulse | | Origin: Developed by the Brit | |
| • | | World Wars I and II and st the United States early in | |
| Under Water: | | | MOLIG MEL 11. |
| Peak Pressure | | Absolute Viscosity, poises:* | |
| Impulse | | Тешр, 85°С 90°С | 53.2 |
| Energy | | • • • | 75 |
| | | Efflux Viscosity, Saybolt Sec | |
| Underground: Peak Pressure | | Temp, 85°C | 5 |
| Impulse | | Heat of: | ## |
| • | | Combustion, cal/gm | 2685 |
| Energy | | Explosion, cal/gm | 1213 |
| | | Gas Volume, cc/gm | 854 |
| | | * Composition using Spec Grad | e Type A, |
| | | | |

Cyclotol, 65/35

| Composition: | Molecular Weight: | 224 |
|--|------------------------------|---------------|
| % RDX 55 | Oxygen Belence: | |
| - | CO: % | -40 - 9 |
| TNT 35 | CO 30 | - 4 |
| | Density: gm/cc Cast | 1.71 |
| | Melting Point: *C | |
| C/H Ratio | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureou of Mine: Apparatus, cm | Boiling Point: *C | |
| Sample Wt 20 mg | Refrective Index, ng | |
| Picatinny Arsenal Apparatus, in. Sample Wt. mg | ng. | |
| | n ₂ | |
| Friction Pendulum Test: | Vocuum Stability Test: | |
| Steel Shoe Unaffected | cc/40 Hrs, at | |
| Fiber Shoe Unaffected | 90°C | |
| Riffe Bullet Impact Test: Trials | 100°C | |
| % | 120°C | |
| Explosions | 135°C | |
| Partials | 150°C | |
| Burned | 200 Grem Bomb Sand Toot: | |
| Unoffected | Sand, gm | 55.4 |
| Explosion Te aporeture: 'C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, g | m |
| 1 | Mercury Fulminate | |
| 5 Decomposes 270 | Lead Azide | |
| 10 | Tetryl | |
| 15 | Sellistic Morter, % TNT: (a) | 134 |
| 20 | Trausi Test, % TNT: | 1,54 |
| 75°C International Host Test: | Plate Dent Test: | |
| % Loss in 48 Hrs | Method | |
| | Condition | |
| 100°C Heat Test: | Confined | |
| % Loss, 1st 48 Hrs | Density, gm/cc | |
| % Loss, 2nd 48 Hrs | Brisonce, % TNT | |
| Explosion in 100 Hrs | | |
| Flammability Index: | Detenation Rate: | M |
| recommendaty insert: | Confinement | None Court |
| Mygrescopicity: % N11 | Condition | Cast |
| angerous and a second | Charge Diameter, in. | 1.0 |
| Volatility: N11 | Density, gm/cc | 1.72 |
| · | Rate, meters/second | 7975 |

Cyclotol, 65/35

| Fragmentelien Test: | | Shaped Charge Effectiveness, TNT = 100: | | |
|--------------------------------|--|--|--------------------------------------|--|
| 90 mm HE, M71 Projectile, Le | WC-91: | Glass Cones Steel | Cones (e) | |
| Density, gm/cc | 1.71 | Hole Valume | | |
| Charge Wt, Ib | 2.253 | Hole Depth 13 | 0 | |
| Total No. of Fragments: | | Color: Yellow Y | | |
| For TNT | 703 | Yellow-b | uff | |
| For Subject HE | 1153 | Principal Geo: Shaped charge bot | Principal Mass: Shaped charge howhs: | |
| 3 inch HE, M42A1 Projectile, L | er KC-5: | especially fragm projectiles, gre | entation HE | |
| Density, gm/cc | 1.71 | projectites, gre | an Ges | |
| Charge Wt, Ib | 0.922 | | | |
| Total No. of Fragments: | | Method of Leading: | Cast | |
| For TNT | 514 | | CEST | |
| For Subject HE | 769 | | | |
| egment Velocky: ft/sec | | Looding Density: gni/cc | 1.71 | |
| At 9 ft At 25½ ft | | Storage: | | |
| Density, gm/cc | | and also | | |
| beleny, gm/cc | | Method | Dry | |
| set (Relative to TNT): | ************************************* | Hazard Class (Quantity-Distance) | Class 9 | |
| Ain | | Compatibility Group | Group I | |
| Peak Pressure | | | | |
| Impulse | | Exudation | | |
| Energy | | | <u>.</u> | |
| Air, Confined: | | Preparation: See Composition B | | |
| Impulse | | Origin: Developed by the Britis World Wers I and II and stand | | |
| Under Weter: | | the United States early in Wo | erdized in Xrld War II. | |
| Peak Pressure | | _ | | |
| Impulse | | Eutectic Temperature, C: | 79 | |
| Energy | | gm REX/100 gm TNT | ١ | |
| Madaman A. | | 79°C 95°C | 4.16 5.85 | |
| Underground: Peak Pressure | | | <i>))</i> | |
| Impulse | | Absolute Viscosity, poises:* | | |
| Energy | | Тешр, 85°с | 30.2 | |
| | | 90°C | 26.0 | |
| Heat of: | * | | | |
| Combustion, cal/gm | 2755 | * Composition using Spec Grade Class A RDX. | Type A, | |
| Explosion, cal/gm | 1205 | Crees & UDA. | | |
| Ges Volume, cc/gm | 845 | | | |
| * Calculated from composi | tion of mixture. | | | |

Cyclotol, 60/40

| Composition: 96 | Melecular Weight: | 224 |
|--|---------------------------------------|-----------|
| RDX 60 | Oxygen Belence: | |
| | CO. % CO % | -43 10 |
| TNT 40 | | |
| | Density: gm/cc Cast | 1.68 |
| | Molting Point: °C | |
| C/H Ratio | Freezing Point: *C | - |
| npost Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 75 | Boiling Point: *C | |
| Sample Wt 20 mg | Refrective Index, no | |
| Picetiriny Arsenal Apparatus, in. 14 | n <u>n</u> | |
| Sample Wt, mg 19 | nai fr | |
| riction Pendulum Test: | | |
| Steel Shoe Unat: | Vecum Stability Test: cc/40 Hrs, at | |
| | Tected 90°C | |
| | 100.C | |
| Iffe Sullet Impact Test: Trials | 120°C | 0.29 |
| % Explosions 5 | 135°C | |
| Porticis 55 | 150°C | |
| Burned 25 | 200 Carro Barak Card Tara | |
| Unaffected 15 | 200 Grem Berab Send Test: Sand, gm | 54.6 |
| | | 74.0 |
| ixplacion Temperature: *C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, g | • |
| 5 Decomposes 280 | Mercury Fulminate | 0.22* |
| 10 | Lead Azide | 0.20* |
| 15 | Tetryl *Alternative initiating cha | rges. |
| 20 | Bellistic Morter, % TNT: (a) | 1.33 |
| | Trousi Toot, % TNT: | |
| 5°C International Heat Test: % Lost in 48 Hrs | Plate Dent Test: (b) | |
| | Method | В |
| 90°C Heat Test: | Condition | Cast |
| % Loss, 1st 48 Hrs | Confined | No |
| % Loss, 2nd 48 Hrs | Density, gm/cc | 1.72 |
| Explosion in 100 Hrs | Brisance, % TNT | 132 |
| emmebility index: | Datenation Rate: | |
| the state of the s | Confinement | None |
| ygrescopicity: % Nil | Condition | Cast |
| , , | Charge Diameter, in. | 1.0 |
| elatility: Nil | Density, gm/cc | 1.72 |
| | Rate, meters/second | 7900 |

Cyclotol, 60/40

| Fregmentetion Test: | | Shaped Charge Effectiveness, TNT = 100: | | |
|-------------------------------------|--------------|--|---------------|--|
| 90 mm HE, M71 Projectile, Let | WC-91: | Glass Cones Steel | Cones (a) | |
| Density, gm/cc | 1.65 | Hole Volume 178 | 162 | |
| Charge Wt, Ib | 2.187 | Hole Depth 125 | 148 | |
| Total No. of Fragments: | | Color: Yel | low-buff | |
| For TNT | 703 | | 200-022 | |
| For Subject HE | 998 | Principal Uses: Shaped charge t | omb: | |
| 3 inch HE, M42A1 Projectile, Lei | KC-5: | especially frag projectiles, gr | mentation HE | |
| Density, gm/cc | 1.67 | projectizes, gr | | |
| Charge Wt, Ib | 0.882 | | | |
| Total No. of Fragments: | | Method of Leading: | Cast | |
| For TNT | 514 | | | |
| For Subject HE | 701 | | | |
| | | Looding Density: gm/cc | 1.68 | |
| Fragment Velocity: ft/sec | (c) 2965 | | | |
| At 9 ft At 25% ft | 2800 2800 | Storage: | | |
| Density, gm/cc | •• | Method | Dry | |
| Blast (Relative to TNT): | (d) | Hazard Class (Quantity-Distance) | Class 9 | |
| Air: | | Compatibility Group | Group I | |
| Peak Pressure | 104 | | | |
| Impuise | 116 | Exudation | | |
| Energy | •• | | | |
| Air, Confined: | | Preparation: See Composition | В | |
| Impulse | | Origin: Developed by the Brit | ish between | |
| | | World Wars I and II and sta | ndardized in | |
| Under Water: | | the United States early in | World War II. | |
| Peak Pressure | | Bulk Modulus at Room | | |
| impulse | | Temperature (25°-30°C): | | |
| Energy | | Dynes/cm ² x 10 ⁻¹⁰ | 4.14 | |
| Underground: Peak Pressure | | Density, gm/cc | 1.72 | |
| Impulse | | Absolute Viscosity, poises:* | | |
| Energy | | Temp, 85°C | 12.3 | |
| liest of: | * `` | 90°C | | |
| Combustion, cal/gm | 2820 | | | |
| Explosion, cal/gm Gas Volume, cc/gm | 1195 845 | * Compositions using Spec Crad Class A RDX- | e Type A, | |
| Compressive Strength: Ib/i | 3 · | | | |

^{*} Calculated from composition of mixture.

Cyclotol, 75/25, 70/30, 65/35

References: 15

- (a) L. C. Smith and E. G. Kyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OCRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) R. W. Drake, <u>Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells</u>, OSRD Report No. 5622, 2 January 1946.
- (d) V. Philipchuk, Free Air Blast Evaluation of ADX-THT-Al, RDX-THT, and THT-Metal Systems, Mational Morthern Summary Report, MM-P-34, April 1956.
- (e) Hastern Laboratory, du Pont, Investigation of Cavity Effect. Section III, Variation of Cavity Effect with Composition, NIRC Contract W-572-ORD-5723.
- (f) W. S. Cramer, Bulk Compressibility Data on Several High Explosives, MAYORD Report No. 4360, 15 September 1956.
 - (g) Also see the following Picatinny Arsenal Technical Reports on Tyclotols:

| 0 | 1 | 2 | 3 | 4 | 2 | <u>6</u> | I | 8 | 2 |
|--------------|--------------|------|----------------------|--------------------------------------|--------------|------------------------------|----------------------|----------------------|----------------------|
| 1290 1530 | 1651 1741 | 1482 | 1483 1793 19°3 | 1824 1834 1944 200 4 | 1435 1585 | 1476 1756 1796 1876 | 1427 1507 1747 | 1398 1488 1838 | 1469 1509 1709 |

(h) C. Lenchitz, W. Beach and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

¹⁵See footnote 1, page 10.

Cyclotrimethylene Trinitrosamine

| Composition: | 2 | Melecular Weight: (C3H6N6O3) | 174 |
|---|-----------------|----------------------------------|------------|
| ີ້ ຂ 0.6 | | Oxygen Belunce: | |
| o-n-n | N-N-0 | CO ₂ % | -55 |
| н 3-5 | T | CO % | -26 |
| N 48.3 H ₂ C | CH ₂ | Density: gm/cc | |
| 0 27.6 | 1 | Melting Point: *C | 105 to 107 |
| C/H Ratio 0.12 | | Freezing Point: 'C | |
| Impact Sansitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | | Boiling Point: *C | |
| Sample Wt 20 mg | | Refrective Index, no. | |
| Picatinny Arsenal Apparatus, in. | 15 to 22 | nº | |
| Sample Wt, mg | 17 to 20 | n _m | |
| Fristian Pandulum Test: | | 1176 | |
| Steel Shoe | Unaffected | Vacuum Stability Test: | (c) |
| Fiber Shoe | Unaffected | cc/40 Hrs, at 90°C 0.20 | |
| Fiber 3108 | Ottallec red | 100°C 9.19 | 3.71* |
| Riffe Bellet Impect Test: Trials | | *Average value of 5 gm sample to | |
| % | | lized from isosmyl alcohol. | |
| Explosions | | | |
| Partials | , | ` | |
| Burned | | 200 Gram Bomb Sand Test: | |
| Unaffected | - | Sand, gm 55 | 9.2 54.1 |
| Explosion Temperature: *C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) | | Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | 0.200** |
| 5 220 | 1 | Leod Azide | 0.100## |
| 10 | | **Alternative initiating charges | 1. |
| 15 | | Bellistic Morter, % TNT: | 12 |
| 20 | | | 130 |
| 75°C International Heat Test: | | Trouxi Test, % TNT: | |
| % Loss in 48 Hrs | | Plate Deat Test: Method | |
| 100°C Heet Test: | | Condition | |
| % Loss, 1st 48 Hrs | 8.79 | Confined | |
| % Loss, 2nd 48 Hrs | 2.98 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisonce, % TNT | |
| · · · · · · · · · · · · · · · · · · · | | - Detenation Rate: | (b) |
| Florimobility Index: | | Confinement | None |
| | | — Condition | Cast |
| Hygrescepicity: % 30°C, 90% RH | 0.02 | Charge Diameter, in. | 1.2 |
| Veletility: | | Density, gm/cc | 1.42 |
| | | • | |

Cyclotrimethylene Trinitrosamine

| Fregmentation Test: | Shaped Charge Effectiveness, THT = | 100: |
|--|--|----------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Stee | Cones |
| Density, gm/cc | Hale Volume | |
| Charge Wt, ib | Hole Depth | |
| Total No. of Fragments: | Calan | |
| For TNT | Color: | Yellow |
| For Subject HE | Principal Uses: Ingredient of pr | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | The state of the s | Occure illier |
| Density, gm/cc | | |
| Charge Wt, Ib | | |
| Total No. of Fragments: | Mathed of Leading: Pressed or o | est with edded |
| For TNT | | t depressants |
| For Subject HE | | - |
| Fregment Velocity: ft/sec | Leading Density: gm/cc S | ee below |
| At 9 ft At 25½ ft | Storege: | |
| Density, gm/cc | Method | Dry |
| Plant (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 |
| Air: Peak Pressure | Compatibility Group | Group M |
| Impulse | Exudation | None |
| Energy | | none |
| chargy | Density at Various Pressures | (F) |
| Air, Confined: | Density at Various Pressures: | 10. |
| Impulse | 1b/inch ² | gm/cc |
| Under Weter: | 2,420 | 1.10 |
| Prok Pressure | 4,830 | 1.23 |
| Impulse | 9,070 | 1.37 |
| _ • · · · | 14,500 | 1.44 |
| Energy | 24,200 33,800 | 1.53 1.57 |
| 01-44- | 42,500 | 1.59 |
| Underground: Peak Pressure | ,,,,, | |
| Impulse | Heat of: | |
| | 0-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1 | on 50 |
| Energy | Combustion, cal/gm Explosion, cal/gm | 3158 876 |
| | Formation, cal/gm | -914 |
| | | , |
| | | |
| | , | |

Cyclotrimethylene Trinitrosanine

Preparation of Herahydro-1,3,5-Trinitroso-s-triazine Cyclotrimethylene Trinitrosamine: (Reference a)

An ammoniscal solution of an amine is prepared by adding aqueous formaldehyde to ammonium hydroxide. The rate of addition of formaldehyde is regulated to maintain a solution temperature of 30° to 35° C.

Sodium nitrite is dissolved in water and the solution or slurry is then poured into the previously prepared amine-exmonia solution and totally dissolved by stirring. This solution is chilled to below 0°C.

Into a mixed acid solution, previously prepared by dissolving concentrated nitric acid in water and adding concentrated sulfuric acid, all chilled to -9°C, there is added the cold amins-nitrite solution below the surface of the acid mixture. The addition is regulated to take 20 to 30 minutes.

The resulting foamy head of cyclotrimethylene trinitroramine is allowed to sit over the icy spent liquor for 1/2 hour and is then collected on a sintered glass funnel and washed to neutrality. The moist cyclotrimethylene trinitrosamine is removed from the funnel and airdried on filter paper. The dry crude product melts at 105° to 107°C. Recrystallization from isosamyl alcohol gives a pure compound melting at 105° to 107°C.

Origin:

Cyclotrimethylene trinitrosamine was discovered in 1888 simultaneously by Griess and Harrow (Ber 21 (1888), p. 2737) and by Mayer (Ber 21 (1888), p. 2883) when sodium nitrite was allowed to react with hexamethylene tetramine in acid solution. This compound was later studied by Duden and Scherff (Ann 288 (1895), p. 218) and by Delépine who determined its heat of formation, which was negative (Bull Soc chim (3) 15 (1896), p. 1199). Because cyclotrimethylene trinitrosamine could be made at first in very poor yield only, it was a long time before it received consideration for practical application as an explosive. However, the study of cyclotrimethylene trinitrosamine was continued and investigations were made as to its behavior in mixtures with other substances (Prof. D. G. Römer "Report on Explosives," BIOSGP 2-HBC 5742).

Destruction by Chemical Decomposition:

Cyclotrimethylene trinitrosamine is easily decomposed by acid or alkali and even by boiling in water.

Cyclotrimethylene Trinitrosamine

High Temperature Decomposition, 0.02 gm in 10 wl Test Tube:

| | Immersed 10 minutes in bath | heated at 50/minute |
|-----|-----------------------------|---------------------|
| | | Temp. CC |
| (1) | Melting begins | 105 |
| | Decomposition begins | 150 |
| | Nitrous gas | 160 |
| | Entire decomposition | 170 |
| (2) | Some bubbles | 110 |
| • • | Very slow decomposition | 150 |
| | Decomposes in 2 minutes | 200 |
| | Decomposes in 40 seconds | 250 |
| | Immediate decomposition | 300 |

Long Term Stability: (b)

Cyclotrimethylene irinitrosamine loosely packed in covered wooden boxes for six years at ambient temperature and protected from the sun:

- 1. Explosi a showed no color change.
- 2. Melting point decreased from 104.5° to $10^{i_1\circ}$ C.
- 3. Coefficient of "Utilisation Practique" decreased from 125.5 to 123.5.
- 4. An Thel Test at 110°C gave no color to iodine starch paper in 15 minutes.

Fusion Tests, Mixtures of Cyclotrimethylene Trinitrosamine and TWT:

| Cyclotrimethylene Arinitrosamine, \$ | Melting Point, C |
|---|---------------------|
| 10 | 74 |
| 20 | i 68 |
| 30 | 62 |
| 30 40 | 55 |
| 42 | 55 (Butectic) |
| | 61 |
| 50 60 | 69 |
| 70 | 77 |
| 95 | 95 |

Datectic Composition With TNT: (b) Rate of Detonation, meters/second

42% Cyclotrimethylene Trinitrosamine 58% TNT

7,000

Iron powier
 Copper powder
 Aluminum powder

Cvclotrimethylen __initrosamine

Reaction of Cyclotrimethylene Trinitrosamine With Other Materials:

| | Slight reaction |
|---|--|
| | Slight reaction |
| | Slight reaction |
| 1 | a. Violent decomposition after 2 hours at 10°C b. Violent decomposition after 10 to 15 minutes at 100°C |
| | No evidence of decomposition after 5 days at 90°C |

(p)

Detonation P.te: (b)

| Conf nement | Paper cartridge | |
|---------------------|-----------------|--|
| C.adition | ressed | |
| harge Diemeter, in. | 1.18 | |
| Rate, meters/second | Density, gm/cc | |
| 5180 | 0.85 | |
| 5760 | 1.00 | |
| 6600 | 1.20 | |
| 7330 | 1-40 | |
| 7600 | 1.50 | |
| 7800 | 1.57 | |

4. 2 parts picric acid + 1 part R-Salt

5. 2 parts nitroglycerin + 1 part R-Smlt

References: 1(

- (a) Arthur D. Little, Inc. Progress Report No. 106, Fundamental Development of High Explosives, April 1955, Contract No. DAI-19-020-501-ORD(P)-33.
- (b) Louis Médard and Maurice Dutour, "Étude Des Proprietés De La Cyclotriméthyléne Trinitrosamine," Mém poudr, 37, 1924 (1954).
- (c) H. A. Bronner and J. V. R. Kaufman, "Synthesis and Properties of R-Salt," PATR in preparation 1959.
- (d) Also see the following Picatinny Arsenal Technical Reports on Cyclotri, ω thylene Trinitrosamine: 1174, 2179.

¹⁶See footnote 1, page 10.

DRX (Depth Bomb Explosive)

| Composition: | Molecular Weight: | 83 |
|---|---|---------------------|
| Annonium Hitrate 21 | Oxygen Belance: | |
| RIX 21 | CO ₂ % | -46 -26 |
| | Deneity: gm/cc Cast | 1.68 |
| TMT 40 | | 1.00 |
| Aluminum 18 | Melting Point: *C | |
| C/H Retio | Freezing Point: "C | |
| Impact Sandhivity, 2 Kg Wt: | Soiling Point: *C | |
| Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. 13 | nºs | |
| Sample Wt, mg 14 | ng. | |
| Friction Pondulum Test: | | |
| Steel Shoe | Vocuum Stebility Test: | |
| Fiber Shoe | cc/40 Hrs, at 90°C | |
| | 100°C | |
| Riffe Bullet Impact Test: Trigls | 120°C | 6.15 |
| % Evales: | 135°C | - · - / |
| Explosions Portiols | 150°C | |
| Burned | | |
| Unaffected | 200 Grem Bomb Sand Test: | 50 5 |
| | Sand, gm | 58.5 |
| Explosion Temperature: 'C | Sunsitivity to Initiation: | |
| Seconds, 0.1. (no cop used) | Minimum Detonating Charge, gr | ř. |
| 5 Ignites 400 | Mercury Fulminate | 0.00 |
| 10 | Leod Azide | 0.20 |
| 15 | Tetryl | 0.10 |
| 20 | Ballistic Morter, % TNT: (a) | 146 |
| TESC International Mass Total | Trouzi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plote Dent Test: (b) | |
| | Method | В |
| 100°C Heat Test: | Condition | Cast |
| % Loss, 1st 48 Hrs | Confined | No |
| % Loss, 2nd 48 Hrs | Density, gm/cc | 1.76 |
| Explosion in 100 Hrs | Brisance, % TNT | 102 |
| | Detenation Rate: (c) | |
| Hommobility Indox. | Confinement | None |
| Flammability Index: | Can distant | Cont |
| Flommebility Index: | Condition | Cast |
| | Condition Charge Diameter, in. Density, gm/cc | Cast 1.6 1.65 |

DBX (Depth Bomb Explosive)

| Becater Sensitivity Test: Condition | (e) Cast | Decempesition Equation: Oxygen, atoms/sec |
|--|-------------------------|---|
| Tetryl, gm | 100 | (Z/sec) |
| Wax, In. for 50% Detonation | 1.35 | Heat, kilocalorie/mole |
| | 1-37 | (ΔH, kcal/mol) Temperature Range, °C |
| Wax, gm | 1.76 | |
| Density, gm/cc | T+ (Q | Phase |
| Heat of: Combustion, col/gm | (d) | Armor Plate Impact Test: |
| Explosion, cal/gm | 1700 | 60 mm Morter Projectile: |
| Gos Volume, cc/gm | | 50% Inert, Velocity, ft/sec |
| Formation, cal/gm | | Aluminum Fineness |
| Fusion, cal/gm | | |
| | | 500-lb General Purpos: |
| Specific Heat: col/gm/*C | (d) | N. s. W. St tooks |
| -5°C, density 1.75 gm/cc | 0.25 | Plate Thickness, inches |
| | | 1 |
| | | 11/4 |
| | | 11/4 |
| | | 134 |
| Burning Rate: | | |
| cm/sec | | Bond Drop Test: |
| Thermal Conductivity: col/sec/cm/°C Density 1.75 gm/cc | 13.2 × 10 ⁻¹ | T7, 2000-16 Sami-Armor-Piercing Bomb vs Concrete: |
| | | Max Safe Drop, ft |
| Coefficient of Expansion: Linear, %/°C -73°-75°C | 4.5 x 10 ⁻⁵ | 500-16 General Purpose Bomb vs Concrete: |
| Volume, %/°C | | Height, ft |
| | | Trials |
| Hardness, Mahs' Scale: | | Unaffected |
| | | Lity Order |
| Young's Modulus: | (á) | High Order |
| E', dynes/cm² | 10.4 x 10.10 | |
| E, Ib/inch² | 1.51 × 10 ⁶ | 1000-lb General Purpose Bomb vs Concrete: |
| Dencity, gm/cc | 1.72 | |
| | | Height, ft |
| Compressive Strength: Ib/inch² (d) | 3210-3380 | Triais |
| Density 1.78 gm/cc | | Unaffected |
| Vapor Pressure: | | Low Order |
| *C mm Mercury | | High Order |
| | | |
| | | |

DBX (Depth Bomb Explosive)

| Fregmentation Test: | Sheped Charge Effectiveness, TNT = 100: | | = 100: |
|--------------------------------------|---|---|-------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | | Glass Cones Ste | el Cones |
| Density, gm/cc | | Hole Vatume | |
| Charge Wt, Ib | | Hole Depth | |
| Total No. of Fragments: | | Celer: | Gray |
| For TNT | | | ozuj |
| For Subject HE | | Principal Uses: | Depth charge |
| 3 inch HE, M42A1 Projectile, | Let KC-5: | · | |
| Density, gm/cc | | · | |
| Charge Wt, Ib | | | |
| Total No. of Fragments: | | Method of Looding: | Cast |
| For TNT | | Ī | |
| For Subject HE | | Leeding Density: gm/cc | 1.61-1.69 |
| Fragment Velocity: ft/sec | | | |
| At 9 ft At 251/4 ft | | Sterege: | |
| Density, gm/cc | | Method | Dry |
| Blast (Relative to TNT): | (d) | Hazard Class (Quantity-Distance) | Class 9 |
| Air: | | Compatibility Group | Group I |
| Peak Pressure | 118 | | |
| Impulse | 127 | Exudation | |
| Ener _{.T} y | 138 | | |
| Air, Confined: | | Preparation: | |
| Impulse | | DBX can be manufactured by | slowly adding |
| Under Weter: | | water-wet RDX to molten TNT | |
| Peak Pressure | | jacketed kettle equipped with all the water has evaporated | |
| Impulse | | is added and with heating and | stirring con- |
| Energy | 136 | tinued, grained aluminum is a ture is cooled with stirring | continued to |
| Underground: Peck Pressure | | maintain uniformity and when ing the mixture is cast. DB | (can also be mad |
| Impulse | | by adding 21% ammonium nitrations to 42% cyclotol or Compos | sition B of 50/50 |
| Energy | | PDX/TNT content plus 1% of the melted at about 100 C. | INT previously |
| | | | |
| • | | | |
| | | | |
| | | | |

DBX (Depth Bomb Explosive)

Origin:

DBX was developed and used by the United States and Great Britain during World War II. References: 17

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, <u>Kethods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.
- (c) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1346.
- (d) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, MAVORD Report No. 87-46, 26 July 1946.
- (e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
 - (f) Also see the following Picatinny Arsenal Technical Reports on DEX: 1585 and 1635.

¹⁷See footnote 1, page 10.

1,3-Dismino-2,4,6-Trinitrobensene (DATMB)

| Composition: | | Melecular Weight: (C6H5N5O6) | | 243 |
|--|-----------------|--|---------|---------|
| C 29.6 | NO ₂ | Oxygen Belence: CO ₃ % CO % | | |
| н 2.1 | NH ₂ | Deneity: gm/cc | Crystal | 1.83 |
| | 40 ⁵ | Melting Point: *C | (a) | 290 |
| C/H Ratio 0.380 | | Freezing Point: *C | | |
| Impact Sonskivity, 2 Kg Wt: | | Beiling Paint: *C | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | | Refrective Index, no | | |
| Picatinny Arsenal Apparatus, in | | | | |
| Sample Wt, mg | 9 | n _{ii} | | |
| , | | n _m | | |
| Friction Pendulum Test: | | Vocuum Stability Test: | | |
| Steel Shoe | | cc/40 Hrs, at | | |
| Fiber Shoe | | 90°C | | |
| Rifle Buflet Impact Test: Triols | , | 100°C | | |
| . % | | 135°C | | |
| Explosions | | 150°C | | |
| Partials | | 130 C | | |
| Burned | | 200 Grem Bomb Send Test: | | |
| Unaffected | | Sand, gm | | 46.6 |
| Explosion Temperature: | 3 | Sensitivity to Initiation: | | |
| Seconds, C.1 (no cop used) | | Minimum Detonating Charg | ge, gm | |
| <u>1</u> | | Mercury Fulminate | | |
| 5 | | Lead Azide | | 0.20 |
| 10 | | Tetryi | | 0.10 |
| 15 | | Bellistic Morter, % TNT: | | 100 |
| 20 | | Treuxi Test, % TNT: | | |
| 75°C International Heat Test: | | | | |
| % Loss in 48 Hrs | | Plate Deat Test: Method | | |
| 10010 Maria Tara | | Condition | | |
| 100°C Heet Test: | 0.00 | Confined | | |
| % Loss, 1st 48 Hrs | 0.00 0.4 | Density, gm/cc | | |
| % Loss, 2nd 48 Hrs | | Brisance, % TNT | | |
| Explosion in 100 Hrs | None | | | |
| Flammability Index: | | Confinement | | None |
| | | — Condition | | Pressed |
| Hygroscopicity: % | | Charge Diameter, in. | | 0.5 |
| | | Density, gm/cc | | 1.55 |
| | | , Density, gm/cc | | 2.00 |

1 3-Dismino-2,4,6-Tri: trobenzene (DATNB)

| At 25½ ft Density, gm/cc Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure | 0 : |
|--|-----------------|
| For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib Total Me, of Fragments: For TNT For Subject HE Leeding Density: gm/cc At 25½ ft Density, gm/cc Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure | ones |
| 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc At 9 ft At 25½ ft Density, gm/cc Method Itset (Relevive to TNT): Ale: Peak Pressure Impulse Energy Air, Cenfined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure | Yellow |
| Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE Loading Density: gm/cc At 50,000 psi At 25½ ft Density, gm/cc Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Under gressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure | |
| Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc At 50,000 psi Storage: Method Storage: Method Method Storage: Method Me | |
| Loading Density: gm/cc At 50,000 psi At 50,000 psi Storage: Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Imp | Pressed |
| At 9 ft At 25½ ft Density, gm/cc Method Method Method Method Method Method Method Method Compatibility Group Peak Pressure Impulse Energy Air, Confined: Impulse Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Method Method Compatibility Group Exudation Cook-Off Temperature: Time, minutes Heat of: Explosion, cal/gm | 1.65 |
| Method Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Confined: Impulse Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Peak Pressure | |
| Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse Energy Cook-Off Temperature: C Time, minutes Heat of: Explosion, cal/gm | Dry |
| Peak Pressure Impulse Energy Air, Confined: Impulse Cook-Off Temperature: OC Time, minutes Heat of: Explosion, cal/gm Cook-Off Temperature: OC Time, minutes Heat of: Explosion, cal/gm Underground: Fack Pressure | |
| Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure | |
| Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure | None |
| Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure | 320 8 |
| Energy Underground: Paok Pressure | 2876 |
| Underground: Paok Pressure | |
| Peak Pressure | |
| | |
| Impulse Energy | |
| | |

Preparation:

Fifty grams (50 gm) of dry styphnic acid was added to 200 gm of anhydrous pyridine with stirring. The resulting slurry was stirred for an additional 30 minutes. The yellow product, dipyridinium styphnate, was collected by filtration and washed with approximately 100 milliliters of diethyl ether. The product was dried over phosphorus (Y) oxide, at room temperature, for 5 hours. Yield of 77 gm (94%), melting point 168° to 170°C (literature melting point 173°C).

To 50 milliliters of phosphorus oxytrichloride, 29.8 gm of the dipyridinium styphnate were added in small portions, with stirring. The reaction mixture was then warmed on a steam bath for 15 minutes. This solution was quenched in 500 gm of ice water. The light yellow precipitate was separated by filtration and washed with water until the washing was neutral to litmus. Yield of 1,3-dichloro-2,4,6-trinitrobenzene 20.4 gm (98%), MP 130 to 131°C (literature MP 128°C).

A suspension of 3 gm of 1,3-dichloro-2,4,6-trinitrobenzene in 9 milliliters of absolute methanol was prepared. This slurry was cooled to 0°C, and dry ammonia was bubbled into the stirred suspension. After 20 minutes the reaction mixture was allowed to warm to room temperature, filtered by suction and washed with methanol and ether until a negative Beilstein test for chloride ion was obtained on the washings. Yield of 1,3-diamino-2,4,6-trinitrobenzene 2.5 gm (7%), MP 288° to 290°C (literature MP 285°C).

Origin:

DATMB, also called 2,4,6-trinitro-1,3-diam.no-benzol or 2,4,6-trinitro-phenylenediamine-(1,3), was first obtained by Noelting and Collin in 1884 (Ber 17, 260) and also by Berr in 1888 (Ber 21, 1546) from 2,4,6-trinitroresorcin dimethylether in contact with ammoniacal alcohol for several days. J. J. Blanksma obtained the same product in 1902 by reacting either 2-chloro-2,4,6-trinitroanisole or 3-chloro-2,4,6-trinitrophenetol with ammoniacal alcohol (Rec trav chim 21, 324) and from 2,4,6-trinitroresorcin methylethyl ether with ammoniacal alcohol (Rec trav chim 27, 56 (1908)).

Meisenheimer and Patzig in 1906 prepared DATMB in the form of yellow needles, MP 280°C from 1,3,5-trinitrobenzene ydroxylamine and sodium methylate in methyl alcohol (Ber 39, 2540). The product was slightly soluble in glacial acetic acid but poorly soluble in other solvents. It decomposed into NH₃ and 2,4,6-trinitroresorcin when boiled with dilute NaOH or KOH (Beil 13,60).

Körner and Contardi prepared DATMB by the reaction of either 2,4-dichloro-1,3,5-trinitro-benzene or 2,4-dibromo-1,2,5-trinitrobenzene with ammoniacal alcohol at room temperature or better by heating to 100°C (Atti R. Accad Lincei (5), 171, 473 (1908)); (5) 18 I, 101 (1909)). A method of preparation by prolonged reaction of N-nitro-N-methyl-2,3,4,6-tetranitroaniline with a saturated ammonia solution was reported in 1913 by van Romburgh and Schopers (Akad Amsterdam Versl 22, 297).

C. F. Van Duin obtained DATNB melting at 301°C by reacting a concentrated aqueous ammonia solution with N-nitro-N,N,N-trimethyl-2,4,6-trinitrophenylenediamine-(1,3) or with N-nitro-N-methyl-N-phenyl-2,4,6-trinitrophenylenediamine-(1,3) (Rec trav chim 38, 89-100 (1919)). Later Van Duin and Van Lennep reacted concentrated aqueous ammonia with 2,4,6-trinitro-3-aminoenisole or 2,4,6-trinitro-3-aminoenhenetol to obtain DATNB melting at 287° to 288°C (Rec trav chim 39, 147-77 (1920)). In 1927 Lorang prepared the same compound by boiling 2,4,6-trinitro-1,3-bis (-nitroethyl ureido) benzene with water or by heating it with ammoniacal alcohol in a tube at 100°C (Rec trav chim 46, 649) (Beil E 17, E II 33).

1,3-Dismino-2,4,6-Trinitrobensene (DATMB)

A recent report describes the preparation of DATHB in two steps from commercially available starting materials. First m-nitroaniline was nitrated with HoSO4-HHO3 acid mixture to tetranitroaniline. The crude tetranitroaniline was converted by methanolic ammonia to disminotrinitro-bensene in a high degree of purity. A conversion of 100 parts of m-nitroaniline into 110 parts of DATHB was obtained by this method, which can easily be carried out on a commercial scale.

Diazodini trophenol

| Composition: | N | Melecular Weight: (C6H2N405) | 510 |
|--|-----------------|---|--------------|
| c 34.3 | 4 | Oxygen Belencs: | |
| н 0.9 | \wedge | CO ₂ % | -61 -15 |
| N 26.7 02N NO2 02 | NO ₂ | Density: gm/cc Crystal | 1.63 |
| 0 38.1 | 0 | Melting Point: *C | 157 |
| C/H Ratio 1.056 | | Freezing Point: 'C | -71 |
| Impact Sensitivity, 2 Kg Wt: | | Beiling Peint: 'C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. | ; (1 lb wt) 7 | <u>-</u> | |
| Sample Wt, mg | 15 | n _m | |
| | | n 🖁 | |
| Friction Pandulum Test: | | Vocuum Stability Test: | |
| Steel Shoe | Detonates | cc/40 Hrs, at | |
| Fiber Shoe | Detonates | - 100°C | 7.6 |
| Riffle Buillet Impact Test: Trials | | 120°C | , |
| % | | 135°C | |
| Explosions Partials | | 150°C | |
| Portios Burned | | 100 Green Bouch Sand Toxes | |
| Unaffected | | 200 Grem Bemb Send Test: Sond, em | 47.5 45.6 |
| | | Sand om Black powder fuse | 45.6 |
| Explosion Temperature: *C Seconds, 0.1 (no cap used) | | Sensitivity to initiation: Minimum Detonating Charge, gm | |
| 1 200 | 1 | Mercury Fulminate | |
| 5 195 | | Lecd Azide | 0.20 |
| 10 180 |) | Tetryl | 0.10 |
| 15 | | D. Milata Ada and Al Sales (a) | |
| 20 | | Bellistic Merter, % TNT: (a) | 97 |
| 75°C International Host Test: | | Trees! Test, % TNT: | |
| % Loss in 48 Hrs | | Plate Dent Test: Method | |
| 100°C Heat Test: | | Condition | |
| % Loss, 1st 48 Hrs | 2.10 | Confined | |
| % Loss, 2nd 48 Hrs | 2.20 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| | | Detenation Rate: | |
| Floroschiller Indor- | | Confinement | |
| Flammability Index: | | Condision Pro | |
| Flemmebility Index: Hygrescepicity: % 30°C, 90% RH | 0.04 | Condition Pres Charge Diameter, in. | ssed |

*Until it is established which picramic acid (melting point 169°C) isomer is involved (Ref: J Chem Soc, 2082, August 1949).

Diazodinitrophenol

| regmentation Test: | Shaped Charge Effectiveness, TNT = | = 100: |
|--|--|--------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones | |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | Color: ye | |
| For TNT | 10 | ellow needles |
| For Subject HE | Principel Uses: Percussion caps | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | |
| Density, gm/cc | | |
| Charge Wt, Ib | | |
| Total No. of Fragments: | Method of Looding: | Pressed |
| For TNT | | |
| For Subject HE | Leading Density: gm/cc Apparer | nt 0.27 |
| regment Velocity: ft/sec | At 3000 pa | i 1.14 |
| At 9 ft | | |
| At 251/2 ft | Storage: | |
| Density, gm/cc | Method | Under water |
| -101 |) Wellioo | Ongel water |
| lest (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 |
| Air: | Compatibility Group | |
| Peak Pressure | | |
| Impulse | Exudation | None |
| Energy | | |
| Air, Confined: | Solubility: | |
| Impulse | | |
| • | Soluble in nitroglycerin, aniline, pyridine, concentra | |
| Under Weter: Peak Pressure | acid, and in most common ore | |
| Impulse | Hean of: | |
| Energy | | |
| | Combustion, cal/gm | 3243 |
| Underground: | Explosion, cal/gm Gas Volume, cc/gm | 8 20 865 |
| Peak Pressure | | • |
| Impulse | Sensitivity to Electrostation Discharge, Joules: | : (b) 0.012 |
| Energy | Discharge, Joures: | (c) 0.01E |
| | | |
| | 1 | |
| | | |
| | | |
| | 1 | |

Diazodinitro ol

Solubility: gm/100 as of the following substances: (c)

Solubility at 50°C

| Sclvent | ₹ | |
|----------------------|---------------------|--|
| Ethyl acetate | 2.45 | |
| Methanol | 1.25 | |
| Ethanol | 2.43 | |
| Ethylenedichloride | 0.79 | |
| Carbon tetrachloride | race | |
| Chloroform | 0.11 | |
| Benzene | 0.23 | |
| Toluene | 0.15 | |
| Petrol: um ether | Insoluble (at 20°C) | |
| Ethyl ether | 0.08 (30°c) | |
| Carbon disulfile | trace (30°C) | |

Preparation: (Chemistry of Powder and Explosives, Davis)

Ten gm of picramic acid is suspended in 120 cc of 5% hydrochloric acid, and under efficient agitation at about 0°C. 3.6 gm sodi: n nitrite in 10 cc water is dumped into the suspension. Stirring is continued for 20 minutes, the product filtered off and washed thoroughly with ice water. The dark brown product, if dissolved in acetone and precipitated in water, turns brilliant yellow.

Origin:

Discovered by Griess in 1858 (Annalen 106, 123; 113, 205 (1800) and studied extensively by L. V. Clark (Ind Eng them 25, 603 (1935). Developed for commercial use in 1928. This compound was patented in the United States by Professor William M. Dane.

Destruction by Chemical Decomposition:

Diazodinitrophenol is decomposed of adding the water-wet material to 100 times its weight of 10% sodium hydroxide. Nitrogen gas is evolved.

- (a) Millip C. Keenan and Dorothy Manas. Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (b) F. W. wow., D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by

¹⁸see footnute :, page 10.

Diszodinitrophenol

Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

(c) L. V. Clark, "Diazodinit-ophenol, A Detonating Explosive," Ind Eng Chem 25, 663 (1933).

Seidell, Solubilities of Inorganic and Organic Compounds, Van Nostrand and Co., N. Y.

(d) Also see the following Picatinny Arsenal Technical Reports on Diazodinitrophenol:

0 2 4 5 7 8 9 150 1352 34 355 827 318 2179 610 214 1838

Diethylene Glycol Dinitrate (DEGN) Liquid

| Composition: % | Melecular Weight: (C4H8N2O7) | 196 |
|--|--|--------------------|
| C 24.5 $\frac{1}{1}$ | Oxygen Belence: CO ₂ % CO % | -4 <u>1</u> - 8 |
| N 14.3 H ₂ C 0 | Density: gm/cc Liquid | 1.38 |
| -1 | Melting Point: °C | 2 |
| 0 57.1 H ₂ Č ONO ₂ C/H Ratio 0.143 | Freezing Point: 'C | · |
| Impact Sacaltivity, 2 Kg Wt: | Soiling Point: 'C Decomposes | 160 |
| Surgou of Mines Apparatus, cm 100+ Sample Wt 20 mg Picatinny Arzenal Apparatus, in. 9 Sample Wt, mg | Cefrective Index, no | 1.4498 |
| Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe | Vecuum Stubility Test: cc/40 Hrs, at 90°C | 0.3cc/20 hr/g |
| Riffe Scilet Impact Test: Trials % | 120°C | 0. 3ee/20 mr/gi |
| Explosions | 150°C | |
| Portials Burned | | |
| Unaffected - | 200 Gram Bomb Send Test: Sand, gm | 42.2 |
| Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 237 | Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetry! | |
| 15 20 | Ballistic Morter, % TNT: | 90 |
| | Treuxi Test, % TNT: | 77 |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Text: Method | |
| 100°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs 4.0 | Con Ined | |
| % Loss, 2nd 48 Hrs 3.0 | Denuity, gm/cc | |
| Explosion in 100 Hrs None | Brisance, % TNT | |
| Flemmebility Index: | Detonation Rate: Confinement | |
| Mygroscopicity: % | Condition Charge Diameter, in. | |
| V-t-attle (-0- / 2: | Density, gm/cc | 1.33 |
| Voletility: 60°C; mg/cm ² /hr 193 | Rate, meters/second | 6760 |

Diethylene Glycol Dinitrate (DEGN) Liquid

| Bosster Sensitivity Test: Condition | | Decomposition Equation: Oxygen, atoms/sec |
|--|--------------|--|
| Tetryl, gm | , | (Z/sec) |
| Wax, in. for 50% Detonation | | Heat, kilocolorie/mole (AH, kcal/mol) |
| Wax, gm | | Femperature Ronge, °C |
| Density, gm/cc | | Phase |
| Meet, of: | | |
| Combustion, cal/gm | 2 792 | Armor Plate Impact Test: |
| Explosion, cal/gm | 841 | 40 mm Adams Burlandle |
| Gas Volume, cc/gm | 796 | 60 mm Morter Projectile: 50% Inert, Velocity, ft/sec |
| Formation, cal/gm | 2020 | Aluminum Fineness |
| Fusion, cal/gm | | , value of the second of the s |
| | | 500-th General Purpose Bombs: |
| Specific Heat: cal/gm., 'C | | Plate Thickness, inches |
| | | 1 |
| | | 114 |
| | | <u>'</u> |
| | | 11/2 |
| Burning Rete: | | 1x4 |
| cm/sec | | Bomb Drop Test: |
| Thermal Conductivity: cal/sec/cm/°C | | T7, 2000-lb Semi-Armor-Hieroing Bomb vs Concrete: |
| Coefficient of Expension: | | Max Safe Drop, ft |
| Linear, %/°C | | 500-lb General Purpocs Bomb vs Concrete: |
| Volume, %/°C | | Height, ft |
| | | — Tri. |
| Fierdness, Mohs' Scale: | | Unafre_red |
| | | Low Order |
| Young's Modulus: | | High Order |
| E', dynes/cm² | | • • • • |
| E, Ib/inch² Density, gm/cc | | 1000-Ib General Purpose Somb vs Concrete: |
| | | — Height, fr |
| Compressive Strength: Ib/inch ² | | Trials |
| | | Unoffected |
| Vapor Pressure: | | Low Order |
| °C mm Mercury | | High Order |
| 20 0.003 | | , " |
| 0.130 | | |
| | | |
| | | |

Diethylene Glycol Dinitrate (DEGN) Liquid

| Fragmentation Test: | Shaped Charge Effectiveness, TNT =: 100: | | |
|---|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hole Vc'ume Hole Depth | | |
| Total No. of Fragments: For TNT | Colorless | | |
| For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: Propellant compositions | | |
| Total No. of Fragments: For TNT For Subject HE | Mathod of Loading: | | |
| Frogment Velocity: ft/sec | Leeding Deasity: gm/cc | | |
| At 9 ft At 25½ ft Density, gm/cc | Storege: Method Liquid | | |
| Blast (Relative to TNT): | Hazard Class (Quentity-Distance) Class 9 | | |
| Air: Peok Pressure Impulse Energy | Compatibility Group Exudation | | |
| Air, Confined: Impulse Under Weter: Peak Pressure Impulse | Preparation: DECN can be prepared with approximately 85% yield by adding diethyleneglyco to mixed acid (50% HNC ₃ , 45% H ₂ SO ₄ , and 5% H ₂ O). The temperature is kept at 30°C or lower. The separated DECN is purified by washing with successive portions of water, dilute sodium carbonate solution and water until neutral. | | |
| Energy Underground: Peak Pressure | Hydrolysis, % Acid: 10 days at 22°C | | |
| Impulse Energy | 301ubility in Water, gm/100 gm, at: 25°C 0.40 60°C 0.60 | | |
| Viscosity, centipolses: Temp, 20°C 8.1 | Solubility, gm/100 gm, at 25°C, in: Ether Alcohol 2:1 Ether:Alcohol 00 | | |

Diethylene Glycol Dinitrate (DEGN) Liquid

Origin:

First prepared and studied by Wm. H. Rinkenbach in 1927 (Ind Eng Chem 12, 925 (1927) and later by Rinkenbach and H. A. Asronson (Ind Eng Chem 23, 160 (1931)) both of Picatinny Arsenal. Used in propellant compositions by the Germans during World War II.

<u>lestruction</u> by Chemical Decomposition:

DECH is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide (Nu2S'9H2O). Heat is liberated by this reaction but this is not hazar lous if stirring is maintained during the addition of DECH and continued until solution is complete.

Reierences: 19

isee the following Picatinny Arsenal Technical Reports on DEGN:

| <u>o</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> | <u>6</u> | I | 2 |
|--------------------------|----------------------------|---------------------------|-------------|-------------|-----------------------------|-----------------------------|--------------------|
| 50 180 620 1490 | 231 551 1391 1421 | 72 602 1282 1392 | 673 1443 | 494 1624 | 346 1516 1616 1786 | 487 1427 1487 1817 | 279 579 1439 |

¹⁹See footnote 1, page 10,

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

| Composition: % | Melecular Weight: (C ₁₀ H ₁₂ N ₄ O ₁₂) | 380 | |
|--|---|----------|--|
| c 31.6 | Oxygen Belence: | | |
| CHCO2CH2C(NO2)2CH2 | CO ₂ % | -59 | |
| н 3.2 | CO % | -17 | |
| н 3.2 снсо ₂ сн ₂ с(Nо ₂) ₂ сн ₃ | Density: gm/cc Crystal | 1.60 | |
| 0 50.5 | Metting Point: °C Form I Form II | 89 86 | |
| C/H Ratio | Freezing Point: *C | | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 100+ | Beiling Peint: °C | - | |
| Sample Wt 20 mg | Refractive Index, no | | |
| Picatinny Arsenal Apparatus, in. 18 Sample Wt. ma 18 | nº | | |
| Sample Wt, mg 18 | ពន្ធ | | |
| Friction Pendulum Test: | | | |
| Steel Shoe Unaffected | Vecuum Stability Test: cc/40 Hrs, at | | |
| Fiber Shoe Unaffected | 90°C | | |
| | '20.C | 0.66 | |
| Kifle Bullet Impact Test: Trials | 120°C | | |
| % | 135°C | 0.91 | |
| Explosions | 150°C | | |
| Portials | | | |
| Burned | 200 Grem Bomb Sand Test: | | |
| Unaffected | Sand, gm | | |
| Explosion Temperature: "C | Sensitivity to Initiation: | | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | | |
| 1 | Mercury Fulminete | | |
| 4 Smokes 250 | · Lead Azide | | |
| 10 15 | Tetryl | | |
| 20 | Ballistic Mortar, % TNT: | | |
| | Trauzi Test, % TNT: | | |
| 75°C International Vicet Test: % Loss in 48 Hrs | Plate Dent Test: Method | | |
| 2444 Mark Tools | Condition | | |
| 100°C Heet Test: | Confined | | |
| % Loss, 1st 48 Hrs | Density, gm, cc | | |
| % Loss, 2nd 48 Hrs | Brisance, % TNT | | |
| | | | |
| Explosion in 100 Hrs | Detenation Rate: | | |
| | | | |
| | Confinement | | |
| Flemmebility Index: | Confinement Condition | | |
| Explosion in 100 Hrs Flammability Index: Hygroscepicity: % | Confinement | 1. ևց | |

CP 706-177

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

| Fregmentation Test: | Shaped Charge Effectiveness, T | NT = 100: |
|--|--|----------------------|
| 90 mm HE, M71 Projectile, Lot WC-91: | Glass Cones | Steel Cones |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | | |
| For TNT | Color: | White |
| For Subject HE | Principal Uses: | |
| 3 inch HE, M42A1 Projectile, Lot KC-5: | Francipal Usas, | |
| Density, gm/cc | | |
| Charge V/t, Ib | | |
| Total No. of Fragments: | | |
| For TNT | Method of Looding: | Cast |
| For Subject HE | | |
| TO Subject the | Looding Density: ym/cc | 1.50 |
| regment Velocity: ft/sec | | • |
| At 9 ft At 251/2 ft | Storage: | |
| Density, gm/cc | 300ga: | |
| Delic ty, griff co | Method | Dry |
| last (Relative to TNT); | Hazard Class (Quantity-Dista | nce) |
| A.r: | Compolibility Grc p | |
| Peak Pressure | | |
| Impulse | Exudation | None |
| Energy | | |
| Air, Confined: | Heat of: | |
| Impulse | Combustion, cal/gm | 3070 (calculated) |
| Under Weter: | Detonation, cal/gm | 707 |
| Peak Pressure | Viscosity, poises: | (calculated) |
| Impulse | Temp, 98.9°C | 0. 5h6 |
| Energy | 106.5°C | 0.435 |
| Underground: | Liquid Density, gm/cc: | |
| Peak Pressure | Тетр, 98.9°С | 1.352 |
| Impulse | 106.5°C | 1.375 |
| Energy | Crisin: | |
| | Conthesized in 1952 by U.C. Mayet Ordnence Labor Maryland. | |

Bis(2,2-Dinitropropyl) Fumarate (DNPF)

Preparation:

(a, b)

fumeryl chloride 2,2-dinitropropenol aluminum bis(dinitropropyl) fumerate chloride

Dinitropropanol was mixed with chloroform (1320 milliliters) and the mixture heated to boiling. The distillate was collected in a water separator. At first the distillate was cloudy and this was dried with calcium chloride before being returned to the system. When no more water was collected in the water separator, the mixture was cooled to room temperature and the separator removed. Fumaryl chloride was introduced, followed by the aluminum chloride which was added in four equal portions. Air was blown into the flask for a minute to effect mixing, and the reaction sustained itself without the addition of heat for one hour. Steam was gradually introduced so that the reflux temperature was reached 2-1/2 hours after the beginning of the reaction. After 3 hours of reflux, the hot liquid was poired into a bucket. As cooling took place the slurry was vigo sly agitated until it finally set up at room temperature. This material was broken up and mixed with dilute ice cold MC1. The solid product was collected on a sintered funnel, washed with water and with heading. The crude material was recrystallized from methanol to give a product melting at 86°C (uncorrected), but after storage for several days the melting point was 89°C.

References: 20

- (e) M. E. Hill. Preparation and Properties of 2,2-Dinitropropanel Esters, NAVORD Report No. 2497, 3 July 1952.
- (b) D. L. Kouba and H. D. McNeil, Jr., Hercules Report on High Explosives. May Contract Nord-11280, Task A, 26 May 1954.

20See footnote 1, page 10.

Bis(2,2-Dinitropropyl) Succinate (DNPS)

| Composition: | Molecular Weight: (C ₁₀ ,11,1N,012) | 382 | |
|--|--|------------|--|
| C 31.4 | Oxygen Belence: CO ₂ % CO % | -63 -21 | |
| M 14.7 CH2CO2CH2C(NO2)2CH3 | Density: gm/cc Crystal | 1.51 | |
| ೦ 50.2 <mark>ರ</mark> ್ವಾಯ್ದದ್ದುರ(೫೦ ₂) ₂ ದಕ್ಕ | Melting Point: *C | 86 | |
| C/H Ratio 0.250 | Frenzing Point: *C | | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparetus cm | Boiling Point: *C | | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | Refrective Index, no | | |
| Friction Fendulura Test: Steel Shoe Fiber Shoe | Vecuus. Stability Test: cc/40 Hrs, at 90°C | | |
| Riffe Bullet Propert Test: Trials Keplosions Partials | - 1,00°C 120°C 135°C 150°C | 0.10 | |
| Burned Unoffected | 200 Grem Bomb Sond Test: Sand, gm | | |
| Explosion Temperature: "C | Sensitivity to Initiation: Minimum Detanating Charge, gm Mercury Fulminate Lead Azide Tetryl Bellistic Morter, % TNT: | | |
| | Trouzi Test, % TNT: | | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: Method | | |
| 100°C Heat Test: % Loss, 1st 48 tirs % Loss, 2nd 48 Hrs Explosion in 100 Hrs | Condition Confined Density, gm/cc Brisonce, % TNT | | |
| Flummability Index: | - Detenation Rate: Confinement | | |
| Hygrascopicity: % | - Condition Charge Diameter, in. | | |
| Volatility: | Density, gm/cc Rate, meters/second | | |

Bis(2,2-Dinitropropyl) Succinate (DNPS)

| Fragmentation Test: | Shepod Charge Effactiveness, TNT = 100: |
|--|--|
| 90 mm EE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Gloss Cones Steel Cones Hole Volume Hole Depth |
| Total No. of Fragments: For TNT | Color: White |
| For Subject HE 3 inch HE, M42A3 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib | Principal Uses: |
| Total No. of Fragments: For TNT For Subject HE | Method of Loading: Cast |
| Fregment Velocity: ft/sec At 9 ft | Loading Density: gm/cc |
| At 251/2 ft Density, gm/cc | Sterage: Method Dry |
| Bleet (Roletive to TNT): Air: | Hazard Class (Quantity-Distance) Compatibility Group |
| Peak Pressure Impulse Energy | Exudotion None |
| Air, Cenfined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy | Origin: Synthesized in 1953 by M. E. Hill of the U.S. Naval Ordnance Laboratory, White Oak, Maryland. |
| | |

Bis(2,2-Dinitropropyl) Succinate (DNPS)

Preparation:

(a)

2CH₃C(NO₂)₂CH₂OH + CH₂COC1 AlCl₃ CH₂COOCH₂C(NO₂)₂CH₃ + CHCl

CH₂COOCH₂C(NO₂)₂CH₃ + CHCl

chloride chloride bis(2,2-dinitropropyl) succinate

A methylene chloride solution of dinitropropanol (0.02 mol in 15 milliliters) was mixed with 0.01 mol of succinyl chloride. To this solution 0.003 mol of crushed anhydrous aluminum chloride was added. It was necessary to cool the reaction vessel due to the vigorousness of the reaction. After 25 minutes at room temperature the reaction solution was refluxed 1-1/2 hours. Fine needle-like crystals formed upon cooling and adding hexane. The crystals were slurried in dilute hydrochloric acid and on recrystallization from methanol gave a 93% yield of INPS (melting point 85° to 85.6°C).

References: 21

(a) M. E. Hill, Synthesis of New High Explosives, NAVORD Report No. 2965, 1 April 1953.

²¹Say footnote !, page 10.

2,2-Dinitropropyl-4,4,4-Trinitroputyrate (DNPTB)

| Composition: % | Molecular Weight: (C ₇ H ₉ N ₅ O ₁₂) | 3 55 | |
|---|---|-------------|--|
| c 23.6 | Oxygen Belence: | | |
| - | CO. % | -29 +2.3 | |
| H 2.5 OCH ₂ C(NO ₂) ₂ CH ₃ | | TE+,) | |
| N 19-7 C 0 | Density: gm/cc Crystal | 1.68 | |
| o 54.2 CH2CH2C(NO3) | Melting Point: °C Form I 11 F Form III 59 | ore II 95 | |
| C/H Ratio | Freezing Point: *C | | |
| Emport Sensitivity, 2 Kg Wt: | Beiling Point: *C | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | Refrective Index, no | | |
| Picotinny Arsenal Apparatus, in: | ng. | | |
| Sample Wt, mg | " | | |
| | n _s | | |
| Folgton Peridulum Test: | Vocuum Stability Test: | ··········· | |
| Studi Shoe | cc/40 Hrs, at | | |
| Fiber Shae | 90°C | | |
| Stills Built Impact Test: Tripls | 100°C | 0.5 | |
| % | 120°C | | |
| Explasions | 135°C | | |
| Portiols | 150°C | | |
| Burned | 200 Gram Bamb Sand Test: | | |
| Unoffected | Sand, gm | | |
| Explosion Temperature: °C | Soughtivity to Initiation: | | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | | |
| 1 5 300 | Mercury Fulminate | | |
| 5 300 10 | Lead Azide | | |
| 15 | Tetryl | | |
| 20 | Ballistic Mortur, % TNT: | | |
| | Truesi Teet, % TRT: | | |
| 75°C International Heat Test: % Loss in 49 Hrs | Plate Dent Test: | | |
| | Method | | |
| 100°C Heat Test: | Condition | | |
| % Loss, 1st 48 Hrs | Confined | | |
| % Loss; 2nd 48 Hrs | Density, gm/cc | | |
| Explosion in 100 Hrs | Brisance, % TNT | | |
| Phone & Mary In Associate | Detenation Rate: | | |
| Fizamobility Index: | Confinement | | |
| Hygrencepialty: % | Condition | | |
| reygrousopheny: 70 | Charge Diometer, in. | ٠ | |
| Voistility: | Density, gm/cc | 1.67 | |
| · · · · · · · · · · · · · · · · · · · | Rate, meters/second | 7600 | |

2,2-Dinitropropyl-4,4,4-Trinitrobutyrate (DNPTH)

| Fragmentali in Yest: | Shaped Charge Effectiveness, TNT | = 100: | | |
|--|--|----------------------------------|--|--|
| 96 mm HR, MF1 Projectile, Let WG-91: | Gloss Cones Str | nel Cones | | |
| Density, gm/cc | Hole Volume | | | |
| Charge Wt, Ib | Hole Depth | | | |
| Yetel No. of Progments: | Color: | White | | |
| For YMT | Comm | WILL CO | | |
| For Subject HE | Principal Uses: | | | |
| 3 lack ME, M42A1 Projectile, Let KC-5: | Village Vest: | | | |
| Density, gm/cc | 1 | . ' ' | | |
| Charge Wt, 1b | - | | | |
| Ciago Wi, II | | | | |
| Total Ma, of Fragments: | | | | |
| For TNT | Method of Loading: | Cast | | |
| For Subject HE | 1 | ,** | | |
| The material of the | Leading Density: grn/cc | 1.67 | | |
| Fragment Valualty: ft/sec | | | | |
| At 9 ft | | | | |
| At 25% ft | Storage: | | | |
| Density, gm/cc | Method | Dry | | |
| | Matthod | Dry | | |
| Heat (Relative to THT): | Hazard Class (Quantity-Distance | Hazard Class (Quantity-Distance) | | |
| | Compatibility Comp | | | |
| Air: Peak Pressure | Compatibility Group | | | |
| hesulae | Exudation | None | | |
| _ | | Mone | | |
| Energy | | | | |
| Ale, Confined: | Heat of: (c) | Solvent | | |
| Impulse | Transition, cal/gm CC | | | |
| | · · | 2 4.8 | | |
| Under Weter: | | | | |
| Peak Pressure | II | 6 -22.0 | | |
| Impulse | Heat of Solution, 30°C: | | | |
| Energy | | olution, cel/gm | | |
| | Material CC. | J. DMF | | |
| Underground: Peck Pressure | Form III 29 | 5 8.1 | | |
| Impulse | Form I 35 | | | |
| | Form II 19 | | | |
| Energy | Crigin. | | | |
| | | | | |
| | Synthesised in 1952 by M. U.S. Naval Ordnance Laborate | | | |
| | Maryland. | | | |

2,2-Dinitropropyl-4,4,4-T.initrobutyrate (IRPIB)

Preparation:

(a, b)

 $GR^3C(RO^5)^5OR + ^{RO^5})^3CGS^5GS^5COCT$

Alal3

dinitropropenol

trinitrobutyryl chloride

aluminum chlorida

CHIO 144

 $CH^{2}C(MO^{5})^{5}CH^{5}COCCH^{5}C(MO^{5})^{3}$ + HCI

dinitropropyl trinitrobutyrate

Dinitropropanol, trinitrocutyryl chloride and eluminum chloride were slowly mixed in carbon tetrachloride at 60°C. This mixture was refluxed at 75°C for two hours. After the reaction was completed, the mixture was cooled and the crystalline product separated and purified. Water in the dinitropropanol was removed by assotropic distillation before the acid chloride was added. The purified product had a melting point of 95°C.

Crystallographic Data:

(c)

Three distinct crystallographic modifications of UMPTS have been observed. These polymorphs have been characterized by means of X-ray diffraction and microscopic observation. Form I crystallizes from solution in carbon tetrachloride, chloroform, acetone, chloroform-hamme, sectone-water, or methanol-water at room temperature. Prolonged standing of Form I at room temperature under the mother liquor promotes a transition to Form II. Upon solidification of molten DMPTB, Form II is always observed.

Linear Rate of Transformation of Form II to Form I (c)

| Temperature, | Average Rate, sq inch/hour | Standard Deviation | Average Rate, mm/hcur |
|--------------|-------------------------------|-----------------------|--------------------------|
| 15 | 0.347 | 0.036 | 0.012 |
| 20 | 0.435 | 0.025 | 0.128 |
| 25 | 0.452 | 0.048 | 0.133 |
| 30 | 0.475 | 0.049 | 0.140 |
| 3 5 | 0.253 | 0.037 | 0.6,5 |

Both Forms I and III gave very erratic sensitivity values. The high temperature polymorph, Form II of DMPTB, gave consistent sensitivity values.

- (a) 3. E. Hill, Preparation and Properties of 2,2-Dinitropropenol Esters, MAYORD Report No. 2497, 3 July 1952.
- (b) W. B. Hewson, Hercule: Report on High Explosives, Mavy Contract MOrd-11280, Task A, 18 October 1954.
- (c) J. R. Holden and J. Wenograd, Physical Properties of an Experimental Castable Explosive 2,2-Dinitropropyl 2,4,4-Trinitrobutyrate DNPTB, MAVORD Report No. 427, 11 December 1956.

²²See footnote 1, page 10.

2,4-Dinitrotoluene (DNT)

| Composition: CF 3 | Moleculer Weight: (C7HcN2O4) | 1.82 | | | |
|--|--------------------------------------|-------|--|--|--|
| c 46.3 | Oxygen Belence: CO ₂ % | -114 | | | |
| н 3.3 | CO % | - 53 | | | |
| N 15.4 | Density: gm/cc | 1.521 | | | |
| Y | Melting Point: *C | 71 | | | |
| 0 35•0 NO ₂ C/H Rotio 0•579 | Freezing Point: *C | | | | |
| Impact Sanshivity, 2 Kg Wt: | Beiling Point: "C Decomposes | 300 | | | |
| Bureou ⁴ Mines Apparatus, cm Sample Wt 20 mg | Refrective index, no | `\ | | | |
| Picatinny Assenal Apparatus, in. | nº. | | | | |
| Somple Wt, mg | ñ o ñ as | | | | |
| Friction Pendulum Test: | Vocuum Stability Test | | | | |
| Steel Shoe Unaffected | cc/40 Hrs, at | | | | |
| Fiber Shoe Uneffected | 90°C | | | | |
| Riffe Builtet Impact Test: Trials | 100°C | 0.04 | | | |
| % | 120°C 135°C | •••• | | | |
| Explosions 0 | 150°C | | | | |
| Pcrtials 0 | 130 € | · | | | |
| Burned 0 | 200 Grem Bomb Sand Tax's | | | | |
| Unaffected 100 | Sond, gm | 19.3 | | | |
| Explosion Temperature: °C | Sensitivity to Initiation: | ` | | | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | | | | |
| 1 | Mercury Fulminate | | | | |
| 5 Decomposes 310 | Leod Azide | 0.20 | | | |
| 10 | Tetryi | 0.25 | | | |
| 15 20 | Bellistic Merter, % TNT: (a) | 71 | | | |
| | Treuzi Test, % TNT: (b) | 64 | | | |
| 75°C International Heat Test: 96 Loss in 48 Hrs | Plate Dent Test: Method | | | | |
| | Condition | | | | |
| 160°C Heat Test: | Confined | | | | |
| % Loss, 1st 48 Hrs | Density, gm/cc | | | | |
| % Loss, 2nd 48 Hrs Explosion in 100 Hrs | Brisonce, % TNT | | | | |
| Explosion in 100 rms | Detenation Rate: | | | | |
| Fig wability Index: | Confinement | | | | |
| | - Condition | | | | |
| Hygrescepicity: % 25°C, 100% P.H 0.00 | Charge Diameter, in. | | | | |
| | Density, gm/cc | | | | |
| Volatility: | Rate, meters/second | | | | |

2,4- initrotoluene (DNT)

| Progmontation Test: | Shoped Charge Effectiveness, TNT = 100: | |
|--|---|--------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones | |
| Density, gm/cc | Hole Volume | |
| Charge Wt, ib | Hole Depth | |
| Total No. of Fragments: | Cofer: Yellow | |
| For TNT | 161108 | |
| For Subject HE | Detector of them. | |
| S look MS AASSAS Bustonelle Las MS S. | Principal Uses: Ingredient of propel powder, dynamites an | |
| 3 Inch HE, M42A1 Projectile, Let KC-5: | plastic explosives | _ |
| Density, gm/cc Charge Wt, ib | | |
| Charge Wt, to | | |
| Total No. of Fragments: | Mark And Local Control Control | |
| For TNT | Method of Leading: Pressed, extruded composition | or cast |
| For Subject HE | | |
| | Leading Density: gm/cc Year | ieble |
| Fragment Velocity: ft/sec | | |
| At 9 ft | • | |
| At 251/4 ft | Storage: | |
| Density, gm/cc | Method Dr: | , |
| | | |
| Heat (Relative to TNY): | Hazard Class (Quantity-Distance) (1) | nes 12 |
| Alm | Compatibility Group Gar | oup D |
| Peak Pressure | × . | |
| Impulse | Exudation | |
| Energy. | | |
| Air, Confined: | 65.5°C KI Test: | |
| Impulse | | |
| | Minutes 60 | • |
| Under Weter: Pack Pressure | Heat of: | |
| Impulse | Combustion, cml/gm (b) 15 | .6 |
| Energy | (0) 134 | • • |
| | Thermal C .ductivity: | |
| Undergreund: | cal, sec/cm/°C | |
| Per Pressure | Density 1.322 gm/cc 6.28 | x 10 ⁻⁴ |
| Imp. alse | 1 | |
| Energy | } | |
| | | |
| | | |
| | | |

2,4-Dinitrotoluene (DNT)

Preparation:

See THT.

Solubility: gm/100 gm of the following substances:

| Bunyl Alcohol | | Mitro | Water | | |
|----------------------------|--------------------------------------|-----------|-------|-----------------|-------------------------|
| °c | ź | <u>°c</u> | 2 | <u>ိင</u> | ź |
| 25 35 45 55 60 | 0.16 0.29 0.49 0.77 1.03 | 20 | 30 | 22 50 100 | 0.027 0.037 0.254 |

301ubility at 15°C, in:

| Solvent | ź | Solvent | ž |
|---|---|---|---|
| CHCH CARC TOLUGI CHCOH CHC CHC | 65.076 2.431 60.644 45.470 5.014 1.916 | CH_COH (absolute) Ether (absolute) Acetone Ethyl acetate CS2 Pyridine | 3.039 7.422 82.931 57.929 2.306 76.810 |

Origin:

Occurs as 75% of the products obtained on the nitration of toluene, the remaining 25% being mainly 2,6-DHT and other isomers of DHT. Also occurs as an impurity in crude THT obtained by standard manufacturing process. used in explosive mixtures at least since 1931.

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Emplosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, ORD Report No. 5746, 27 December 1945.
- (b) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
 - (c) Report AC-2861.
 - (d) Also see the following Picatinny Arsenal Technical Reports on DKT:

| <u>o</u> | 1 | 2 | 3 | <u>4</u> | 2 | <u>6</u> , | I | <u>8</u> | 2 |
|---------------------|--|--|---|--|--------------|-----------------------------|------------------|--------------------|--|
| 810 18 30 | 1351 1501 1651 1781 1821 2031 2221 | 72 372 922 1142 1672 1692 | 43 233 343 673 1023 1663 1743 2013 | 394 804 1044 1084 1164 1324 1464 1524 1674 1751 | 1615 2125 | 186 1556 1816 1896 | 97 817 837 | 768 938 1538 | 69 149 249 279 779 1749 |

²³See footnote 1, page 10.

Dipentaerythritol Hemmitrate (DPEHN)

| Onygen Belence: CO ₂ % CO % | -26 |
|--|---|
| | -20 - 3 |
| Benuity: gm/cc Crystal | 1.63 |
| Melting Point: *C | 73-7 |
| Freesing Point: *C | |
| Boiling Point: 'C | |
| Refrestive Index, ng | |
| 1 | |
| | |
| | |
| 90°C | • |
| — 100°C | 3.7 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |
| 200 Grem Bomb Sand Test: | |
| Sand, gm | 57.4 |
| Sessitivity to initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl | |
| Bellistic Merter, % TNT: (a) | 142 |
| Truck Test, % THT: (b) | 128 |
| Plate Beat Test: Method | |
| Condition | |
| | |
| | |
| | |
| Confinement (c) | Copper tube |
| Condition Charge Diameter, in. | Pressed |
| Density, gm/cc | 1.59 7410 |
| | Preceing Point: "C Belling Point: "C Refrective Index, non non non non non non non non non no |

Mipentaerythritol Hexanitrate (DPEHN)

| Fragmentation Test: | Shoped Charge Effectiveness, TNT = 100: | | | |
|--|---|--|---|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Gloss Cones | Steel Cones | | |
| Density, gm/cc | Hole Volume | | 1 | |
| Charge Wt, ib | Hole Depth | | | |
| Total No. of Fragments: | Color: | White | ł | |
| For TNT | | with CG | | |
| For Subject HE | Principal Uses: Ingredies | at of priming | 1 | |
| 3 lack HE, M42A1 Projectile, Let KG-5: | compositi | | [| |
| Density, gm/cc | | | 1 | |
| Charge Wt, Ib | | | | |
| Total No. of Fragments: | Method of Londing: | Pressed | 1 | |
| For TNT | | | ļ | |
| For Subject HE | | | } | |
| | Leading Density: gm/cc | | 1 | |
| Fragment Velocity: ft/sec At 9 ft | At 3000 to 4000 psi | 1.59 |] | |
| At 251/4 ft | Storoge: | | | |
| Density, gm/cc | Method | Dry | | |
| Blast (Relative to TPIT): | Hazard Class (Quantity-Distr | once) Class 9 | _ | |
| Air: Peak Pressure | Compatibility Group | | 1 | |
| Impulse | in-udation | | | |
| Energy | | ······································ | | |
| Air, Centiced: Impulse | Preparation: (Chemistry Amplosives, Davis) | of Powder and | | |
| Under Weter: | 2(HO-CH ₂) ₄ C Dehydra | time. | | |
| Peak Pressure | (HO-CH ₂) ₃ C-O-C(CH ₂ -O | | 1 | |
| impulse Energy | (0 ⁵ MO-CH ⁵) ³ C-O-C(CH ⁵ | -0m02/3 | | |
| Energy | | manitrate is procured | | |
| Undergreund: | in the pure stat: (melt fractional cryst: llizat | | ļ | |
| Peak Pressure | from moist acetone. | TON OF STREET | Ì | |
| Impulse | Ovigin: Formed as an im | purity in the prepa- | | |
| Energy | ration of PETN. Prop by W. Frederick and W (Berichte 63, 2861 (1 | erties first described Brün in 1930 | | |
| | Heat of: | | | |
| | Combustion, cal/gm | 2260 | 1 | |

Dipentaerythritol Hemanitrate (IPEHR)

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OCRD Report Bo. 5746, 27 December 1945.
 - (b) A. Stettbacher, Me Schiess und Sprengstoffe, Leipsiz, p. 363.
- (c) T. L. Mavis, The Chomistry of Fowder and Explosives, John Wiley and Sons, Inc., New York (1943) pp. 218-253.
- (d) S. Livingston, Characteristics of Emplosives HOK and IPEHN, PATR No. 1561, 6 September 1945.

²⁴See footnote 1, page 10.

Dynamite, Low Velocity, Picatinny Arsenal (LVD

| Composition: 99.5/0.5 RDX/1-MA dye* 17.5 | Molecular Weight: |
|--|---|
| % | |
| TWT 67.8 Tripentaerythrito! 8.6 | Oxygen Selence: CO, % |
| 68/32 Vistac No 1/DOS binders** | CO % |
| Callulose acetate, LH-1 2.0 | |
| *RDX, Class E; 1-MA is 96% pure 1-methylamino- anthraquinone. | Beauty: gm/cc Londing 0.9 |
| **Vistac No 1 is low MW polybutene; DOS is dioctylsebacate. | Meliting Point: 'C |
| C/H Ratio | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: Burgou of Mines Apparatus, cm | Belling Peint: 'C |
| Sample Wt 20 mg | Refractive Indea, no |
| Picatinny Arsenal Apparatus, in. 22 | n ₂ |
| Sample Wt, mg 19 | n _m |
| Friction Pondulum Test: | Vo:sum Stability Test: |
| Steel Shoe Unaffected | cc/40 Hrs, at |
| Fiber Shoe Unaffected | 90°C |
| | - 100°C |
| Riffle Bullet Impact Test: Tricks | 120°C 0.90 |
| % | 135°C |
| Explosions | 150°C |
| Portiols | |
| Burned | 200 Grein Bomb Sond Tost: |
| Unaffected | Sand, gm 40.5 |
| Explosion Temperature: "C | Sanithirty to initiation: |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm |
| 1 | Mercury Fulminate |
| 5 Ignites 480 | Lead Azide 0-20 |
| 10 | Tetryl 0.15 |
| 15 | Builtistic Conton, % (AT: 00 |
| 20 | Trough Test, No. 73: 7: 92 |
| 75°C International Heat Test: | Plate Boot Test. |
| % Loss in 48 Hrs | Method |
| 100°C Heat Test: | Condition |
| % Loss, 1st 48 Hrs | Confined |
| % Loss, 2nd 48 Hrs | Density, gm/cc |
| Explosion in 100 Hrs | Brisance, % TNT |
| | Detraction Rate: |
| Flammability Index: | Confinement None |
| | Condition Hard tamped |
| Hygrescapicity: % 0.31 | Charge Diameter, in. 1.25 |
| 71°C. 95% RH. 30 days Satisfactory | Density, gm/cc 0.9 |
| Veletility: | Rate, meters/second 4577; or 14400 ft/sec |

Dynamite, Low Velocity, Picatinny Arsenal (LVD)

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: |
|---|--|
| 90 mm HE, M73 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Conus Steel Cones Hole Volume Hole Depth |
| Total No. of Fragments: For TNT | Color: Pink |
| For Subject HE 3 inch NG, M4PAQ Projectile, Let KG-S: Density, gm/cc Charge Wt, Ib | Pulnciped Uses: Excavation, demolition, and cratering |
| Votel Ma, of Fragments: For TNT For Subject HE | Method of Looding: Hall Packer machine looded |
| Frequent Velocity: ft/sec At 9 ft At 251/2 ft | Leading Density: gm/cc 0.9 Thumped cartridge 1-1/2" diameter, 8" long Storage: |
| Density, gm/cc Start (Relative to TNT): | Method Dry Hozord Class (Quantity-Distance) Class 9 |
| Air: Peak Pressure Impulse Energy | Compatibility Group Group A Exudation |
| Air, Confined: Impulse | Sensitivity to Initiation: Stick dry, No. 6 Electric cap Stick dry, Corps of Engineers Stick wet, Corps of Engineers Positive |
| Under Weter: Peak Pressure Impulse | Air Gap Propagation: Max distance will, inch 2-1/2 min distance will not, inch 3 Stick Water Immersion: |
| Energy Underground: Peak Pressure Impulse Energy | Weight gein, \$ 9-16 Heat of: Explesion, cal/gm 625 Gas Volume, ce/gm 611 Cold Storage: Plastic to -65°F Low Temperature Usage: -65°F, 1 day, M2 cap crimper Satisfactory |

Preparation:

To date this dynamite has been prepared on a laboratory scale, the details of which are classified. It has been shown, however, to be machine loadable on a Hall packing sachine.

Origin:

第15年まままで

Hobel invented the original dynamite in 1866 and gave the name dynamite to mixtures of mitroglycerin and kieselguhr. The strength of a dynamite was indicated by the percentage of M3 in the mixture. Later oxidants and combustibles were substituted for the kieselguhr, and ammonium nitrate and/or nitrostarch replaced the M3, bringing into existence new types of dynamites. World War II military operations required special demolition and crate ing emplosives free from the objectionable characteristics of M3 and many "dynamite substitutes" were developed for specific applications. The subject low velocity dynamite was developed in 1956 by Picatimny Arsen() (Ref a).

- (a) H. W. Veigt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamics, PA Technical Report 2374, March 1957.
 - (b) Also see the following Picutimny Arsenal Technical Reports on Dynamites:

| <u>o</u> | 1 | 2 | <u>4</u> | 2 | <u>6</u> | I | <u>8</u> | 2 |
|------------------------------|--------------|--------------|-------------|------|------------------------------|------------|-------------|------|
| 1260 1360 1720 1760 | 1381 1611 | 782 1531: | 864 1464 | 1285 | 1416 1436 1506 2056 | 507 957 | 848 1828 | 1819 |

²⁵See footnote 1, page 10.

Dynamite, Medium Velocity, Hercules (MVD)

| Melecular Weight: |
|---------------------------------|
| Oxygen Selence: |
| CO. % -51 |
| CO % |
| Density: gm/cc Londing 1.1 |
| Density: gm/cc Loading 1.1 |
| Malting Peint: *C |
| Freezing Point: *C |
| Mitroglycerin Equivalent, \$ 60 |
| Refrective Index, no |
| I |
| n <u>s</u> |
| n _m |
| Vecuum Stability Test: |
| cc/40 Hrs, at |
| 90°C |
| - 100°C 0.80 |
| 120°C 0-94 |
| 135°C |
| 150°C |
| |
| 200 Gram Bomb Sand Test: |
| Sand, gm 52.6 |
| Sansitivity to 1 sitiation: |
| Minimum Detonating Charge, gm |
| Marcury Fulminate |
| Lead Azide 0.20 |
| Tetryl 0.10 |
| |
| Ballistic Marter, % TNT: 122 |
| Trouzi Test, % TNT: |
| Plate Dent Test: |
| Method |
| Condition |
| Confined |
| Density, gm/cc |
| Brisc nce, % TNT |
| L'atomation Rate: |
| Confinement None |
| Condition Machine tamped |
| Charge Diameter, in. 1.50 |
| |
| Density, gm/cc 1.1 |
| |

AMOD 104.177

Dynamite, Medium Velocity, Herculas (MVD)

| Fragmentation Test: | Shoped Charge Effectiveness, TXT = 109: | | | |
|--|---|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones | | | |
| Density, gm/cc | Hole Volume | | | |
| Charge Wt, lb | Hole Depth | | | |
| Total No. of Fragments: | Color: Buff | | | |
| For TNT | Bull | | | |
| For Subject HE | Principal Uses: Excavation, demolition, and | | | |
| 3 inch HE, MAZA1 Projectile, Let KC-5: | cratering | | | |
| Density, gm/cc | | | | |
| Charge Wt, Ib | | | | |
| Total No. of Fragments: | Method of Leeding: Hall Packer machine loaded | | | |
| For TNT . | months of country and | | | |
| . For Subject HE | | | | |
| | Leading Density: gm/cc 1-1 | | | |
| Fregment Valuality: ft/sec | Cartridge 1-1/2" diameter, 8" long | | | |
| At 9 ft | | | | |
| At 251/4 ft | Storege: | | | |
| Density, pin/oc | Method Dry | | | |
| Bloot (Relative to TNT): | Hazard Class (Quantity-Distance) CLass 9 | | | |
| Air: Peak Pressure | Compatibility Group Group A | | | |
| | Exudation | | | |
| Impulse | · | | | |
| Energy | } | | | |
| Air, Confined: Impulse | Sensitivity to Initiation: Stick dry, No. 6 Electric cap Positive Stick dry, Corps of Engineers Positive Stick wet, Corps of | | | |
| Under Water: | Engineers > 50% Positive | | | |
| Peak Pressure | Air Gap Propagation: | | | |
| Impulse | Max distance will, inch 1 | | | |
| Energy | Min distance will not, inch 2-1/2 | | | |
| • | Quarry Performance: 4 tons rock/ton explosive | | | |
| Undergreend: Peck Pressure | Stick Water Immersion: | | | |
| Impulse | Weight gain, % 25-27 | | | |
| Energy | Heat of: Explosion, cal/gm 935 Gcs Volume, cc/gm 945 | | | |
| | Cold Storage: Plastic to -70°F . | | | |
| • | Low Temperature Usage: -65°F, 1 day, M2 cap crimper Satisfactory | | | |

Dynamite, Medium Velocity, Hercules (MVD)

Preparation:

Manufactured on standard dynamite line and packaged on a Hall packing machine. Details of handling materials and techniques of manufacture are classified.

Origin:

Military forces frequently require exceptition, demolition, and cratering operations for which standard high explosives are unsuitable. Commercial blasting explosives, except black powder, are called dynamites although they may contain no nitroglycerin. The subject dynamite substitute was developed in 1952 by the Hercules Powder Company (Ref a).

- (a) W. R. Baldwin, Jr., Blasting Explosives (Dynamite Substitute), Hercules Powder Company Formal Progress Report, RI 2086, 15 August 1952, Army Contract DA-36-034-0RD-110.
- (b) H. W. Voigt, Development of Low-Velocity Military Explosives Equivalent to Commercial Dynamites, PA Technical Report No. 2374, March 1957.

²⁶See footnote 1, page 10.

EC Blank Fire

| Composition: % | | Melecular Weight: Approximately 503 |
|---|--------------|-------------------------------------|
| Witrocellulose, 13.25% N | 80 | Oxygen Selence: |
| Barium Mitrate | 8 | CC ₂ % +5 |
| Potassium Nitrate Starch | 8 3 | CO % -25 |
| Diphenylamine | 0. 75 | Density: gm/cc |
| Aurine | 0.25 | Melting Point: 'C |
| C/H Ratio | | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: | | Boiling Point: *C |
| Bureau of Mines Apparatus, cm | 19 | Palastina Index |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. | | Refrective Index, no |
| Sample Wt, mg | 20 | n _{as} |
| | | r.º |
| Friction Pondulum Test: | | Yecsum Stebility Test: |
| Steel Shoe | Snaps | cc/40 Hrs, at |
| Fiber Shoe | | 90°C |
| Rifle Bullet Impact Test: Trials | | 100°C |
| · • | | 120°C |
| % Explosions | | 135°C |
| Partials | | 150°C |
| Burned | | 200 Gram Bamb Sand Test: |
| Unaffected | | Sand, gm 46.8 |
| Explosion Temperature: °C | | Sensitivity to Initiation: |
| Seconds, 0.1 (no cop used) | | Minimum Detonating Charge, gm |
| 1 | | Mercury Fulminate 0-22 |
| 5 Decomposes 20 | 0 | Lead Azide |
| 10 | | |
| 15 | | Tetryl |
| 20 | | Ballistic Morter, % TNT: |
| | | Trouzi Test, % TNT: |
| 75°C International Heat Test: % Loss in 48 Hrs | 1.8 | Plate Dest Test: |
| A FORE III AG LIIS | 1.0 | Method |
| 100°C Heat Test: | | Condition |
| % Loss, 1st 48 Hrs | 2.0 | Confined |
| % Loss, 2nd 48 Hrs | 0.2 | Density, gm, fcc |
| Explosion in 100 Hrs | None | Brisance, % TNT |
| | | Detenation Rate: |
| Flammability index: | | Confinement |
| | | Condition |
| Hygrescepicity: % 30°C, 90% RH | 6.2 | Charge Diameter, in. |
| | | Density, gm/cc |
| Volatility: | | Rate, meters/second |

EC Blank Fire

| Fragmontation Test: | Shaped Charge Effectiveness, Ti-I' = 100: | | |
|---|---|----------------|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Concs Steel | Cones | |
| Density, gm/cc | Hole Volums Hole Depth | | |
| Chorge Wt, Ib | | | |
| Total No. of Fragments: | Color: | | |
| For TNT | J | | |
| For Subject HE | Principal Uses: Grenades; caliber .30 blank | | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | | |
| Density, gm/cc | | | |
| Charge Wt, Ib | | | |
| Total No. of Fragments: | Metho' of Looding: | Loose | |
| For TNT | | | |
| For Subject HE | Loading Density: gm/cc | 0.40 | |
| Fragment Velocity: ft/sec | | | |
| At 9 ft At 251/4 ft | Sierege: | | |
| Density, gm/cc | | | |
| | Method | Wet | |
| Blast (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 0 | |
| Air | Compatibility Group | Group J | |
| Feak Pressure |] | | |
| Impulse | Exudation | | |
| Energy | | · | |
| Air, Conflaed: Impulse | Preparation: EC Blank Fire is a partially colloided propellant manufactured by a cess using either acetone and ethanol or mixture of butyl acetate and benzene to | | |
| Under Weter: Pook Pressure | gelatinize only a part of the lose. The process is control | ne nitrocellu- | |
| Impulse | the product passes through a | | |
| Energy | and is retained on a No. 50 Origin: | DTCAG. | |
| Underground: | Invented in 1882 as bulk spe | | |
| Peak Pressure | less) powder by W. F. Reid and | D. Johnson at | |
| Imputse Energy | the Explosive Company (whence in England (Eritish Patent 619) | | |
| eferences: 27(a) See the following Picatinny | 120°C Heat Test: | Winner- | |
| rsenal Technical Reports on EC Blank Fire: 891 | | Minutes 150 | |
| D1, 372, 512, 822, 233, 1373, 854, 65, 667, 17, 69, 579 and 1399. | Red Fumes | 300+ | |
| LI, UZ, JIZ BANG ADZZ. | Explodes | 300+ | |

²⁷ See footnote 1, page 10.

| Composition: | Molecular Weight: | 178 | | |
|---|-------------------------------|---------------------------------------|--|--|
| % Haleite (Ethylene Dinitramine) 55 | Oxygen Belence: | · · · · · · · · · · · · · · · · · · · | | |
| Haleite (Ethylene Dinitramine) 55 | CO. % | -51 -17 | | |
| TNT 45 | CO % | -17 | | |
| | Density: gm/cc Cast | 1.62 | | |
| | Melting Point: 'C Eutectic | 80 | | |
| C/H Rat v | Freezing Point: 'C | | | |
| Impost Sensitivity, 2 Kg Wt: Bursou of Mines Apparetus. cm 95 | Beiling Point: °C | | | |
| Bureau of Mines Apparatus, cm 95 Sample Wt 20 mg | Refrective Index, no | | | |
| Picatinny Arsenal Apparatus, in. | 02 | | | |
| Sample Wt, mg 20 | 62 | | | |
| Friction Pandulum Test: | <u> </u> | | | |
| Steel Shoe Unaffected | Vocuum Stability Test: | | | |
| Fiber Shoe Unaffected | cc/40 Hrs, at 90°C | | | |
| | - 100°C | 1.0 | | |
| Rifle Bullet Impact Test: Trials | 120°C | 11+ | | |
| % Explosions 0 | 135°C | | | |
| Partials 0 | 150°C | | | |
| Burned 7 | 200 Grem Bomb Sand Yest: | | | |
| Unaffected 93 | Sand, gm | 49.4 | | |
| Explanica Temperature: * °C | Sensitivity to Initiation: | | | |
| Seconds, 0.1 (no cop used): 435 | Minimum Detonating Charge, gr | 1 | | |
| 1 248 | Mercury Fulminate | 0.22* | | |
| 5 Decomposes 190 | Lead Azide | 0.26* | | |
| 10 183 | *Alternative initiating char | | | |
| 15 176 | Ballistic Mortus, % THT: (a) | | | |
| 20 168 | | 119 | | |
| *Composition Haleite/TNT, 60/40. | Trough Test, % TMT: (b) | 120 | | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Deat Yest: | 52/48 | | |
| | Method | В | | |
| 100°C Heat Test: | Condition | Cast | | |
| % Loss, 1st 48 Hrs 0-2 | Confined | No | | |
| % Loss, 2nd 48 Hrs 0.1 | Density, gm/cc | 1.62 | | |
| Explosion in 100 Hrs None | Brisance, % TNT | 112 | | |
| Planet Allen Indon 1971 | — Detenation Rate: | | | |
| Flammability Index: Will not continue to burn | Confinement | None | | |
| Hygrescovicity: % None | Condition | Cast | | |
| V VIIIV | Charge Diameter, in. | 1.0 1.63 | | |
| Veletility: | Density, gm/cc | 7340 | | |
| | Rate, meters/second | 1 300 | | |

Ednatol, 55/45

| regmentation Test: | | | Shoped Charge Effectiveness, TNY | = 100 : <u>50/50</u> |
|--------------------------------|----------|-------------|---|-----------------------------|
| 98 mm HE, M71 Projectile, Le | 4 WC-91: | . | Gloss Cones Str | rel Cones |
| Density, gm/cc | 1.56 | 1.62 | Hole Volume 126 | 123 |
| Charge Wt, Ib | 2.065 | 2.092 | Hole Depth 117 | 121 |
| Total No. of Fragments: | | | A.1 | 37 - 3 3 |
| For TNT | 703 | 703 | Color: | Yellow |
| Fox Subject HE | 842 | 905 | Principal Usus: Projectiles, | bombs; special |
| 3 inch HE, MAZAT Projectile, L | at KC-5: | | ammunition co | |
| Density, gm/cc | | 1.60 | | |
| Charge Wt, Ib | | 0.845 | | |
| Total No. of Fragments: | | | Method of Londing: | <u></u> |
| For TNT | | 514 | | Cast |
| For Subject HE | | 536 | | |
| | | | Looding Density: gm/cc 1.65 | |
| regment Velocity: ft/sec | | 2730 | | |
| At 9 ft At 251/2 ft | | 2430 | Storege: | |
| Density, gm/cc | | 1.62 | Method | Dry |
| Heat (Relative to TNT): | | (d, e) | Hozard Class (Quantity-Distance) | Class 9 |
| Air: | | | Compatibility Group | Group I |
| Peak Pressure | | 108 | | |
| Impulse | | 110 | Exudation Does | not exude at 6500 |
| Energy | | 10 8 | | |
| Air, Confined: | | | Eutectic Temperature, °C: | 79. 8 |
| Impulse | | | gm Haleite/100 gm TNT 79.80C | 0.48 |
| | | | 95.0°C | 1.12 |
| Under Weter: | | | | |
| Peak Pressure | | | Compatibility with Metals: | |
| Impulse | | •• | Dry: Brass, aluminum, ste mild steel, mild steel coate | |
| Energy | | 113 | proof black paint, and mild | steel plated |
| Underground: | | | with cadmium or nickel are uper, magnesium, magnesium, | |
| Peak Pressure | | | mild steel plated with coppe | |
| Impulse | | | slightly affected. | |
| Energy | | | Wet: Copper, brass, magne | |
| Booster Sensitivity Test: | | (à) | aluminum alloy, mild steel, | mild steel coated |
| Condition | | Cast | with scid-proof black paint | |
| Tetryl, gm | | 100 | plated with copper, cadmium, | |
| Wax, in. for 50% Detone | tion | 1.28 | are heavily attacked. Alumi affected and stainless steel | |
| Density, gm/cc | | 1.62 | | 'n mieriecoen. |

Preparation:

Wet Haleite is added slowly to molton TNT heated at about 100° C in a steam jacketed melting kettle equipped with a stirrer. Heating and stirring are continued until all moisture is evaporated. Loading is done by pouring the mixture cooled to 85° C.

Origin:

Mixtures of Haleite (EINA) and TNT, designated Ednatol; were developed at Picatinny Arsenal just prior to World War II.

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) Fhilip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, MAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, <u>Methods of Physical Testing</u>, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, ROL Meso 10,303, 15 June 1949.
- (e) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, <u>Investigation of Cavity Effect</u>, Sec III, Variation of Cavity Effect with Composition, NURC Contract W-672-ORD-5723.
- (g) Eastern Laboratory, du Pont, Investigation of Cavity Effect. Final Report, 18 September 1943, MIRC Contract W-672-ORD-5723.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Ednatol:

| <u>o</u> | 1 | 2 | . 3 | 4 | 2 | <u>6</u> | 7 | <u>8</u> | 2 |
|------------------------------|----------------------|----------------------|----------------------|--------------|----------------------|----------|------------------------------|----------------------|--------------|
| 1290 1400 1420 1530 | 1091 1451 1651 | 1162 1372 1482 | 1193 1363 1493 | 1294 1434 | 1325 1395 1885 | 1796 | 1457 1477 1737 1797 | 1198 1388 1838 | 1279 1469 |

²⁸See footnote 1, page 10.

Ethylene Glycol Di-Trinitrobutyrete (GTNB)

| Composition: | Molecular Weight: (C10H12N6O16) | 468 | | | |
|--|--|----------|--|--|--|
| С 25.6 н 2.6 | Oxygen Belence: CO ₂ % CO % | -34 O | | | |
| и 17.1 (н ² co ² cH ² cH ² c(но ³) | Density: gm/cc Crystal | 1.63 | | | |
| о 54.7 сн ₂ со ₂ сн ₂ сн ₂ с(nо ₃) | Molting Point: *C | ,96 | | | |
| C/H Ratio 0.235 | Freezing Point: *C | | | | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | Boiling Point: "C | | | | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | Refrective Index. no. no. | | | | |
| Friction Pundulum Yest: Steel Shoe Fiber Shoe | Vectum Stability Test: cc/40 Hrs, at 90°C 100°C | | | | |
| Riffe Suffer Impact Test: Tricks Keplosions | 120°C | | | | |
| Portiols | 150°C | | | | |
| Burned Unaffected | 200 Grem Bemb Send Test: Sand, gm | | | | |
| Explosion Temperature: *C Seconds, 0.1 (no cap used) 1 5 50% point 230 | Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl | | | | |
| 15 20 | Ballistic Morter, % TNT: | | | | |
| | Trougi Test, % TNT: | | | | |
| 75°C International Host Test: % Loss in 48 Hrs | Plate Dent Test: Method | - | | | |
| 100°C Heet Test: | Condition Confined | | | | |
| % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs | Density, gm/cc | | | | |
| Explosion in 100 Hrs | Brisonce, % TNT | | | | |
| Flommobility Index: | Detenation Rate: Confinement | | | | |
| Hygrescapicity: % | Condition Charge Diameter, in. | | | | |
| | Density, gm/cc | | | | |

Ethylene Glycol Di-Trinitrobutyrete (GTNB)

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | |
|---|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hole Volume Hole Depth | | |
| Total No. of Fragments: For TNT | Color: | | |
| For Subject HE 3 lash HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: Casting medium for HE compour | | |
| Total No. of Fragments: For TNT For Subject HE | Method of Leading: Cast | | |
| Fragment Velocity: ft/sec | Leading Develty: gm/cc 1.60 | | |
| At 9 ft At 251/4 ft | Sterege: | | |
| Density, gm/cc | Method Dry | | |
| Blast (Relative to Th(T): | Hazard Class (Quantity-Distance) | | |
| Air: Peak Pressure Impulse Energy | Compatibility Group Exudation None | | |
| Air, Confined: Impulse | Preparation: (a) By the addition of nitroform to ethylene glycol discrylate. As the method of prepa- | | |
| Under Weter: Peak Pressure Impulse | ration often leads to products difficult to purify, a preparation from ethylene glycol and pure trinitrobutyric acid is in process | | |
| Energy | Origin: | | |
| Underground: Peak Pressure Impulse | First synthesized in 1951 by the U.S. Rubber Company, Research and Development General Laboratories, Passaic, New Jersey. | | |
| Energy | Viscosity, poises: | | |
| | Temp, 98.9°C 0.246 106.5°C 0.193 | | |
| | Liquid Density, gm/cc: Temp, 98.9°C 1.467 106.5°C 1.459 | | |

Ethylene Glycol Di-Trinitrobutyrate (GTNB)

- (a) U. S. Rubber Company Progress Report No. 14, Navy Contract Nord-10129, 1 February 1951 to 1 May 1951.
- (b) U. S. Naval Ordnance Laboratory, Silver Spring, Maryland, Letter from Dr. O. H. Johnson to Commanding Officer, Picatinny Arsenal, 8 April 1955 (ORDBB 471.86/44-3, Registry No. 39815); and MOL Letter from Dr. D. V. Sickman to Commanding Officer, Picatinny Arsenal, 29 November 1955 (ORDBB 471.86/159-1; Serial No. 32894).

²⁹See footnote 1, page 10.

Explosive D (Ammonium Picrate)

| Composition: | Molecular Waight: (C6H6N407) | 246 |
|--|--|--------------|
| % C 29.3 O 用illy | Oxygen Belensus CO ₂ % CO % | -52 -13 |
| H 2.4 02N NO2 | Density: gm/cc Crystal | 1.72 |
| N 22.7 | Melting Point: *C Decomposes | 265 |
| 0 45.6 C/H Retio 0.317 | Freening Point: *C | 207 |
| | Beiling Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 17 | Refrective Index, no ao | 1.508 |
| Sample Wt, mg 1.8 | po | 1.870 |
| | - c _o | 1.907 |
| Friction FonAulum Test: | Vector Stability Test: | |
| Steel Sho Unaffected | cc/40 Hrs, at | |
| Fiber Shoe Unarrected | — 100.c | 0.2 |
| Rifle Bullet Import Test: Trials | 120°C | 0.4 |
| % | 135°C | 0.4 |
| Explosions 0 | 150°C | 0.4 |
| Partials 0 | 150 € | |
| Burned 30 | 200 Grem Sumb Send Test: | |
| Unaffected 70 | Sand, gm | 39.5 |
| Explosion Temperature: 'C | Sonsitivity to Initiation: | |
| Seconds, 0.1 (no cop used) 405 | Minimum Detonating Charge, gm | |
| 1 367 | Mercury Fulminate | |
| 5 Decomposes 318 | Leod Azide | 0.20 |
| 10 314 | Tetryl | 0.0 6 |
| 15 299 20 295 | Sellistic Merter, % THT: (a) | 99 |
| | Treesi Test, % TNT: | |
| 75°C international Heat Test: % Loss in 48 Hrs | Plate Dont Test: | |
| | Method | Α |
| 100°C Heat Test: | Condition | Pressed |
| % Lnss, 1st 48 Hrs 0.1 | Confined | Yes |
| % Loss, 2nd 48 Hrs 0.1 | Density, gm/cc | 1.50 |
| Explosion in 100 Hrs None | Brisance, % TNT | 91 |
| | Detenation Rate: | |
| Flummobility Index: | Confinement | None |
| Managements of a good | Condition | Pressed |
| Hygrescepicity: % 100% RH 0.1 | Charge Diameter, in. | 1.0 |
| Volatility: | Density, gm/cc | 1.55 |
| · • • • • • • • • • • • • • • • • • • • | Rate, meters/second | 6850 |

Explosive D (Ammonium Picreta)

| 90 non HE, M71 Projection, Let W. Dennity, gm/cc Charge Wt, Ib Tatel No. of Fragments: For TNT For Subject HE 3 Inch HE, M42A1 Projectio, Let (Dennity, gm/cc Charge Wt, Ib Tatel No. of Fragments: For TNT For Subject HE | 1.50 1.94 703 649 KC-S: 1.55 0.82 | Hole Volume Hole Depth Celer: | Yellow-orange |
|---|--|---|-------------------|
| Charge Wt, Ib Total Ma. of Fragments: For TNT For Subject ME 3 Inch ME, M42A1 Projectile, Let I Density, gm/cc Charge Wt, Ib Total Ma. of Fragments: For TNT For Subject ME | 1.94 703 649 KC-S: 1.55 0.82 | Color: Principal Uses: AP projecti: | les and bombs |
| Total No. of Fragments: For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let i Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE | 703 649 KC-S: 1.55 0.82 | Color: Principal Uses: AP projecti | les and bombs |
| For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let I Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE | 649 KC-5: 1-55 0.82 514 | Principal Uses: AP projecti | les and bombs |
| For Subject HE 3 Inch HE, M42A1 Projectile, Let (Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE | 649 KC-5: 1-55 0.82 514 | Principal Uses: AP projecti | les and bombs |
| 3 Inch HE, M42A1 Projectile, Let (Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE | 1.55 0.82 514 | | |
| Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE | 1.55 0.82 514 | | |
| Density, gm/cc Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE | 1.55 0.82 514 | Method of Leading: | |
| Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE | 0.82 514 | Method of Leading: | |
| For TNT For Subject HE | • . | Method of Loading: | |
| For TNT For Subject HE | • . | . Attended of Leading: | |
| | • . | | Pressed |
| Programme A Market Control | 508 | | |
| | | Leeding Density: gm/cc PS1 : | x 10 ³ |
| regment Velocity: ft/sec | | 1.33 1.41 1.47 1.4 | |
| At 9 ft At 251/4 ft | | Storage: | |
| Density, gm/cc | | | |
| bulling, gray at | | Method | Dry |
| Hest (Relative to TNT): | | Hazard Class (Quantity-Distance | class 9 |
| Ain | | Compatibility Group | Group I |
| Frak Pressure | | 1 | |
| Impulse | | toudation | None at 65°C |
| Energy | | | |
| Ale, Confined: | | Sensitivity to Electrostat:Discharge, Joules: | ic (d) |
| Impulse | | | (~/ |
| Under Weter: | | Through 100 Mesh: | |
| Peak Pressure | | Confined Unconfined | 6.0 0.025 |
| Impulse | | | |
| Energy | | Booster Sensitivity Tesu: | (c) |
| | | Condition Tetryl, gm | Pressed 100 |
| Underground: | | Wax, in. for 50% Detons | |
| Peak Pressure | | Density, gm/cc | 1.54 |
| impules | | Heat of: | |
| Energy | | Combustion, cal/gm | 2890 |
| | | Explosion, cal/gm | 800 |
| | | Formation, cal/gm | 395 |

Preparation:

Explosive D is manufactured by suspending picric acid in hot water and neutralizing it with gaseous or liquid ammonia. As the picrate is formed, it goes into solution; on cooling, it precipitates. An excess of ammonia leads to formation of the red form of ammonium picrate. This should be avoided. The separated crystals are washed with cold water and dried.

Effect of Storage on Sand Test Values:

Minimum Detonating Charge

| Stor Years | ege oc | Fulminate (gm) | Tetryl (gm) | Sand Crushed (gm) |
|---------------|-----------|-------------------|----------------|-------------------------|
| 0 | | | 0.06 | 23 |
| 3.5 | 50 | 0.25 | | 23 |
| ž * | Normal | | 0.03 | 23 |
| 4 * | Mormal | | 0.04 | 23 |
| 2 ** | 50 | 0.24 | | 23 |

After 3.5 years at 50°C.
 After 3.5 years at 50°C and 2 years at magazine temperature.

Solubility: gm/100 gm (\$), of: (e)

| <u>Vie</u> | ater Alcohol Ethyl Acetat | | | | 1 Acetate |
|------------|---------------------------|---------------------------|---|-----------------------------|---|
| °c | £ | °c | ٠ ٤ | <u>°c</u> | 1 |
| 20 100 | 1.1 75 | 0 10 30 50 80 | 0.515 0.690 1.050 1.890 3.620 | 0 10 . 30 50 80 | 0.290 0.300 0.380 0.450 0.560 |

Origin:

First prepared by Marchand in 1841 and used by Brugere in admixture with potassium nitrate as a propellant in 1869. Used as a high explosive after 1900.

Destruction by Chemical Decomposition:

Explosive D (ammonium picrate) is decomposed by dissolving in 30 times its weight of a solution made from 1 part of sodium sulfide (Na₂S-9H₂O) in 6 parts of water.

References: 30

(e) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III - Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.

³⁰See footnote 1, page 10.

Explosive D (Ammonium Picrete)

- (b) D. P. MacDougall, Methods of Physical Testing, OGRD Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Welton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, .OL News 10,303, 15 June 1989.
- (d) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
 - (e) Various sources in the open literature.
 - (f) Also see the following Picatinny Arsenal Technical Reports on Explosive D:

| <u>o</u> | <u>1</u> | <u>2</u> | 3 | 4 | 2 | . <u>6</u> | 1 | <u>8</u> | 2 |
|--------------------|--------------|--|-----|-----------------------------------|---|--|--------------|--------------------|-------------------------------|
| 340 870 1383 | 14k1 35 1 | 132 582 1172 1352 1372 1492 | 843 | 694 704 874 1234 1724 | 65 425 1585 1655 1725 1885 1895 | 266 556 796 986 1466 1796 | 1737 1797 | 328 838 1838 | 1 729 1 75 9 |

Glycerol Monolectate Trinitrate (GLTN) Liquid

| Composition: | Meleculer Weight: (C6H9N3O11) 299 |
|--|--|
| H 3.0 CH ² -0-C-CH-CH ³ | Oxygen Belence: CO ₂ % -30 CO % 3 |
| N 14.1 CH-ONO2 | Density: gm/cc Liquid 1.47 |
| сн ₂ — оно ₂ | Molting Point: *C |
| C/H Ratio 0.180 | Freezing Point: *C |
| Impact Sensitivity, 2 Kg We: Bureau of Mines Apparatus, cm 15 (1 1b vt); 42 Sample Wt 20 mg | Refrective Index, no |
| Picatinny Arsenal Apparatus, in. Sample Wt, mg | n _m 1.464 |
| Friction Pend in Test: Steel Shoe Unaffected Fiber Shoe Unaffected | Vecuum Stability Test: cc/40 Hrs, at 90°C |
| Rifle Bullet Impact Yest: Triols Explosions Portiols | 100°C 5.9 120°C 135°C 150°C |
| Burned Unoffected | 200 Green Bomb Sond Test: Sond, gm 13-1 |
| Explosion Temperature: 'C Seconds, 0.1 (no cap used) 1 5 223 10 15 | Secultivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Load Azide Tetryl |
| 20 | Bellietic Merter, % TNT: |
| TRACE And the Address of the Address | Trousi Test, % THT: |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Deat Test: Method |
| 100°C Heat Test: | Condition Confined |
| % Loss, 1st 48 Hrs 2.5 % Loss, 2nd 48 Hrs 1.8 | Density, gm/cc |
| Explosion in 100 Hrs None | Brisance, % TNT |
| Flummability Index: | Detenation Rate: Confinement |
| Hygreecepicity: % | Condition Charge Diameter, in. |
| Veletility: 60°C, mg/cm²/hr 28 | Density, gm/cc Rate, meters/second |

Glycerol Monolactate Trinitrate (GLTN) Liquid

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: | |
|---|---|------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones · | |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | Color: | |
| For TNT | | |
| For Subject HE | Principal Uses: Gelatinizer for nitrocellul | Lose |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | |
| Density, gm/cc | | |
| Charge Wt, Ib | | |
| Total No. of Fragments: For TNT | Method of Loading: | |
| For Subject HE | Leeding Density: gm/cc | |
| Brown and Makashar da Jana | | |
| Fregment Velocity: ft/sec At 9 ft At 25½ ft | Storage: | |
| Density, gm/cc | | |
| | Method Liquid | |
| Blast (Relative to TNT): | Hozard Class (Quantity-Distance) Class | 9 |
| Air: | Compatibility Group | |
| Peak Pressure | | |
| Impulse | Exadation | |
| Energy | | |
| - | Hydrolysis, % Acid: | |
| Air, Confined: | 10 days at 22°C 0.021 | |
| Impulse | 6 days at 60°C 0.021 | |
| Under Weter: | Solubility in Water, | |
| Peak Pressure | gm/100 gm, at: | |
| Impulse | 2:5°c <0.01 (60°c <0.015 | |
| Energy | | |
| No decrease de | Solubility, gm/100 gm, at 25°C, in: | |
| Underground: Peok Pressure | | |
| Impulse | Ether 2:1 Ether:Alcohol | |
| Energy | Acetone | |
| | Heat of: | |
| | Combustion, cal/gm 2407 | |
| | Community Cal/8m | |
| | | |
| | | |

Glycerol Monolactate Trinitrate (GLTM) Liquid

Preparation:

Glycerol monolectate (GML) is prepared by heating a glycerol lactic acid mixture containing \$4 excess lactic acid at \$116°C for \$112\$ hours with dry air bubbling through the liquid. The product which contains 0.67% free acid is carefully mixed with 6 parts of \$40/60 HMO3/HgSOh maintained at 20°C, stirred for 1 hour, cooled to 5°C, and poured on ice. It is extracted with ether, water-washed, adjusted to pH 7 by shaking with a sodium bicarbonate solution, and again water-washed three times. It is then dried with calcium chloride, filtered and freed of ether by bubbling with air until minimal loss in weight is obtained. The product has a nitrate-nitrogen content of 13.43% (theoretical 14.1% N). Another batch, prepared from RML obtained from glycerol-lactic acid containing 6.5% excess glycerol, had a nitrate-nitrogen content of 14.30%, corresponding to a mixture containing 5.5% nitroglycerin. It is not considered practicable to prepare the pure GLTN.

Origin:

The preparation of a nitrated ester of lactic acid and glycerol, by nitrating a glyceryl lactate with nitric and sulfuric acids, for use in explosives, was reported in 1931 by Charles Stine and Charles Burke (U. S. Patent 1,792,515).

The preparation of glycerol monolactate by heating glycerol with equimolar proportions of a lactic acid ester of an alcohol boiling below 100°C (ethyl lactate) was patented by Richie H. Locke in 1936 (British Patent 456,525 and U. S. Patent 2,087,980).

Reference: 31

(a) P. F. Macy and A. A. Saffitz, Explosive Plasticizers for Nitrocellulose, rATR No. 1616, 22 July 1946.

³¹See fcoinote 1, page 10.

Glycol Dinitrate (GDN) Liquid

| Compasition: | Molecular Weight: (C2H4N2O6) | 152 | | | |
|---|-----------------------------------|---------------|--|--|--|
| c 15.8 ONO ₂ | Oxygen Belence: | | | | |
| H 2.6 CH ₂ | CO: % | 0.0 21 | | | |
| N 18.4 | Bensity: gm/cc Liquid, 25°C | 1.48 | | | |
| 0 63.2 | Melting Point: "C | -20 | | | |
| C/H Rotio 0.092 | Freezing Point: *C | | | | |
| Impact Sensitivity, 2 Kg Wt: | Boiling Point: *C | | | | |
| Bureau of Mines Apparatus, cm 4 (1 1b vt); 56 Sample Wt 20 mg | Refrective Index, no | | | | |
| Picatinny Arsenal Apparatus, in. Sample Wt, mg | na | 1.4452 | | | |
| | กตุ | | | | |
| Friction Pendulum Test: | Vacuum Stability Test: | | | | |
| Steel Shoe | cc/40 Hrs, at 90°C | | | | |
| Fiber Shoe | 100°C | | | | |
| Rifle Sullet Impect Test: Trials | 120°C | | | | |
| % | 135°C | | | | |
| Explosions | 150°C | | | | |
| Portiols Burned | | | | | |
| Unaffected | 200 Gram Bamb Sand Test: Sand, gm | | | | |
| Explosion Temperatura: "C | Sensitivity to Initiation: | | | | |
| Seconds, 0.1 (no cop used) | Minimum Detonating Charge, gm | | | | |
| l 5 Evplodes 257 | Mercury Fulminate | | | | |
| 10 | Lead Azide | | | | |
| 15 | Tetryl | | | | |
| 20 | Ballistic Morter, % TNT: | | | | |
| | Trouzi Test, % TNT: | | | | |
| 75°C International Hoot Test: % Loss in 48 Hrs | Plate Dent Test: Method | | | | |
| 100°C Heet Test: | Condition | | | | |
| % Loss, 1st 48 Hrs | Confined | | | | |
| % Loss, 2nd 48 Hrs | Density, gm/cc | | | | |
| Explosion in 100 Hrs | Brisance, % TNT | | | | |
| Flommobility Index: | Detonation Rate: Confinement | Glass tube | | | |
| | Condition | Liquid | | | |
| Hygrescopicity: % 30°C, 90% RH 0.00 | Charge Diameter, in. | Liquia 10 | | | |
| | Density, gm/cc | 1.485 | | | |
| Veletility: | 1 | 7300 and 2050 | | | |

Glycol Dinitrate (GDN) Liquid

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | | | |
|--|---|--|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones | | | | |
| Density, gm/cc | Hole Volume | | | | |
| Charge Wt, Ib | Hole Depth | | | | |
| Total No. of Fragments: | Color: Yellow | | | | |
| For TNT | Color: Yellow | | | | |
| For Subject HE | Principal Uses: Ingredient of nonfreezing | | | | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | dynamite | | | | |
| Density, gm/cc | | | | | |
| Charge Wt, Ib | | | | | |
| Total vior of Fragments: | Method of Leading: | | | | |
| For TNT | | | | | |
| For Subject HE | Leading Density: gm/cc | | | | |
| Fragment Velocity: ft/sec | | | | | |
| At 9 ft At 251/2 ft | Storage: | | | | |
| Density, gm/cc | Method Liquid | | | | |
| Blast (Relative to TNT): | Hazard Class (Quantity-Distance) Class 9 | | | | |
| Ale: | Compatibility Group | | | | |
| Peck Pressure | | | | | |
| Impulse | Exudation | | | | |
| Energy | | | | | |
| Air, Confland: | Solubility in 1000 cc Water: | | | | |
| Impulse | Temp, OC Grams | | | | |
| | 15 6.2 | | | | |
| Under Weter: Peak Pressure | 20 6.8 50 9.2 | | | | |
| Impulse | Viscosity, centipoises: | | | | |
| Energy | Temp, 20°C 4.2 | | | | |
| Underground: | Vanor Pressure: | | | | |
| Peok Pressure | OC mm Mercury | | | | |
| Impulse | 0.0044 | | | | |
| Energy | 20 0.038 | | | | |
| -, | 40 0.26 60 1.3 | | | | |
| | 60 1.3 80 5.9 | | | | |
| | 100 22.0 | | | | |
| | Heat of: | | | | |
| | Combustion, cal/gm 1764 | | | | |
| | Formation, cal/gm (b) 366 | | | | |

Preparation:

Glycol dinitrate (ethylene glycol dinitrate, dinitroglycol, nitroglycol, dinitrodimethyleneglycol) may be prepared by nitration of ethylene glycol, HOCH2CH2OH, with a mixed nitric acid in the same apparatus that is used for the preparation of nitroglycerin. The glycol is prepared by synthesis from ethylene, and ethylene chlorohydrin:

$$CH_2 = CH_2 \xrightarrow{\text{HOC1}} \text{HOCH}_2CH_2C1 \xrightarrow{\text{H}_2O} \text{HOCH}_2CH_2OH$$

Origin:

Henry was the first to prepare and identify glycol dinitrate (Ber 3, 529 (1870) and Ann chim phys [4] 27, 243 (1872) but Kekulé had previously nitrated ethylene and obtained an unstable oil which he supposed to be glycol nitrate-nitrate. No immediate practical use was added of glycol dinitrate because glycol itself was relatively rare and expensive at the time. It was 1904 before a patent was granted covering the use of GDN as an explosive (DRP 179,789), but it was seven years later before its actual use as an explosive was recorded (Mém poudr 16 (1911) p. 214). The principal physical properties of GDN were determined or recorded by Rinkenbach (Ref b).

- (a) Ph. Maoum, <u>Mitroglycerin and Mitroglycerin Emplosives</u>, translation, E. M. Symmes, The Williams and Wilkins Company, Baltimore (1928), p. 224.
 - (b) Wm. H. Rinkenbach, "The Properties of Glycol Dinitrate," Ind Eng Chem 18, 1195 (1926).
- (c) Wm. H. Rinkenbach, "Glycol Dinitrate in Dynamite Manufacture," Chem Met Eng, 34, 296 (1927).
- (d) Wm. H. Rinkenbach, Application of the Vacuum Stability Test to Nitroglycerin and Nitroglycerin Explosives, PATR 1624, 27 August 1946.

³²See footnote 1, page 10.

| Composition: | | Molecular Weight: | 93 |
|---|------------------|---|--------------|
| RDX 45 | | Oxygen Selence: | |
| TITT 30 | | CO ₂ % | -66 -66 |
| Aluminum 20 | | CO % | - 3 6 |
| D-2 Wax 5 | | Density: gm/cc Cast | 1.74 |
| Calcium Chloride, added 0.5 | | Melting Point: °C | |
| C/H Ratio | | Freezing Point: *C | |
| It nect Sensitivity, 2 Kg Wt: Bureou of Mines Apparatus, cm | | Boiling Point: 'C | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. (c) 14 Sample Wt, mg 18 | | Refractive Index, no | |
| Friction Pendulum Test: | | Vocuum Stability Test: | |
| • | ffected | cc/40 Hrs, at | |
| Fiber Shoe | | 90°C | 0.47 |
| Rifle Bullet Impact Test: Trials (b) | | | 0.41 |
| % | | 135°C | |
| Explosions 80 | | 150°C | |
| Partiols | | 130 C | |
| Burned | | 290 Grem Bomb Sand Test: | |
| Unaffected 20 | | Sand, gm | 49.5 |
| Explosion Temperature: *C (a) Seconds, 0.1 (no ccp used) | | Sensitivity to Initiation: Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 610(min) | (c) | Lead Azide | 0.20 |
| 10 | • • | Tetry! | 0.10 |
| 15 | | | |
| 20 | | Bellistic Morter, % TNT: (d) | 135 |
| 75°C International Heat Test: | | Trouzi Test, % TNT: | |
| % Loss in 48 Hrs | | Plate Dent Test: Method | |
| IGO'C Heet Test: | | Condition | |
| % Loss, 1st 48 Hrs 0-7 | 8 | Confined | |
| % Loss, 2nd 48 Hrs 0.0 | | Density, gm/cc | |
| Explosion in 100 Hrs Non | | Brisance, % TNT | |
| | | Detenation Rate: | (a, b) |
| Flommability Index: | | Confinement | None |
| Museum de la company of the company | - 0 0 | — Condition | Cast |
| Hygreecepicky: % 30°C, 95% RH, 7 day 71°C, 95% RH, 7 day | s 2.01 s 1.77 | Charge Diameter, in. | 1.0 |
| Voletility: | | Density, gm/cc | 1.71 |
| | | Rate, meters/second | 7191 |

| Beester Sensitivity Test: Candition Tetryl, gm 1Yax, in. fo: 50% Detanation Wax, gm Density, gm/cc | | Decomposition Equation: Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) Temperature Range, *C. Phase |
|--|--|--|
| Neet of: Combustion, cal/gm Explosion, cal/gm | 3972 923 | Armer Plate Impact Test: 60 mm Mortur Projectile: |
| Gas Volume, cc/gm Formation, cal/gm Fusion, cal/gm 178 ⁰ C (b) | 733 | 50% Inert, Velocity, ft/sec Aluminum Fineness |
| Fusion, cal/gm 18°C (b) Specific Heat: c, um/°C | 10.25 (b) | 500-th General Purpose Bembe: |
| 30°C | 0.269 | Plate Thickness, inches |
| 50°C | 0.268 | 1 11/4 11/4 18/4 |
| Burning Rate: cm/sec | /h\ | Bomb Drop Test: |
| Thermal Conductivity: cal/sec/cm/*C 35°C | (b) -3 | T7, 2000-16 Semi-Armor-Piercing Bomb vs Concrete: |
| Coefficient of Expansion: Linear, Al/Inch 0°C 35°C | 40 x 10 ⁻¹ 4 83 x 10 ⁻¹ 4 | Max Safe Drop, ft 500-16 General Purpose Bemb vs Concrete: |
| 70°c | 131 × 10 ⁻¹ | Height, ft Trials |
| Mardness, Mohs' Scale: | | Unaffected Low Order |
| Yenng's Medulus: E', dynes/cm² | (b) 9.0 x 10 ⁹ 5 | High Order |
| E, lb/inch² Density, gm/cc | 1-30 x 10 ⁷ 1-71 | 1000-16 Goneral Purpose Somb vs Concrete: |
| Compressive Strength: Ib/inch2 | See below | Height, ft Trials Unaffected |
| Veper Pressure: *C mm Mercury | | Low Order High Order |
| Compressive Strength: lb/inch Density, gm/cc Ultimate deformation, % | 1083 1.71 1.32 | |

| 90 man HE, M71 Projectile, Let ECS-1-17: Density, gm/cc Chorpe Wt, ib Total Na. of Prognasati: For Composition B 998 For Subject HE 714 For 30/20 Tritona) 616 3 inch HE, MAZA1 Projectile, Let KC-5: Density, gm/cc Chorpe Wt, ib Total Na. of Prognasati: For TNT For Subject hiE Leeding Density: gm/cc At 25½ ft Density, gm/cc Method of Lording: Cast | Fregmentation Test: | (b) | Shaped Charge Effectiveness, TNT = ' | 100: |
|--|--|-------------|--------------------------------------|-----------|
| Charge Wt, lb Total Na. of Fragmants: For Composition B 998 For Subject HE 714 For 30/20 Tritona). 616 3 inch NE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Total Na. of Fragmants: For TNT For Subject NE Leeding Dansity: gm/cc 1.71 Impuse NFOC Pendulum 19.8 Energy Leading Class (Quantity-Distance) Air, Confined: Impulse Lender Velocity: Impulse Leading Class (Quantity-Distance) Exudation None Exudation None Leudor Weter: Peack Pressure Impulse Lender Pessure Impulse Lender Pessure Impulse | | -17: | | Cones |
| Tatel No. of Fregments: For Composition B 998 For Subject HE 714 For 30/20 Tritona). 616 3 inch NE, M42A1 Projectile, Lot KC-5: Density, gm/cc Charge Wt, lb Tatel No. of Fregments: For TNT For Subject NE Leading Dansity: gm/cc 1.71 Inguined Velocity: ff/sec Ar 9 ft At 25½ ft Density, gm/cc Method of Lording: Cast Formula Dansity: gm/cc 1.71 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compositivity Group Group I Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Landor Weter: Peak Pressure Impulse | | | | |
| For Composition B 998 For Subject HE 714 For 80/20 Tritona). 616 3 inch HE, M02A1 Projectile, Let KC-5: Density, gm/cc Chorge Wt, lb Tetal Ma, of Fregments: For TNT For Subject HE Leading Dansity: gm/cc 1.71 Method of Lerding: Cast Leading Dansity: gm/cc 1.71 Method Dry Method Dry Method Dry Method Dry Ale: 3.25" diameter sphere Peack Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Lader Weter: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Underground: Peack Pressure Impulse | Charge Wt, Ib | | Hole Depth | |
| For Composition B 998 For Subject HE 714 For 30/20 Tritonal. 616 3 inch HE, MAZA1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Tetal No. of Prognesse: For TNT For Subject HE At 2514 ft Density, gm/cc Ale: 3.25" diameter sphere Peok Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Land Peok Pressure Impulse Energy Land Pressure Impulse Energy Land Research Let Masses Principal Uses: HE charge Principal Uses: HE charge | Total No. of Fragments: | | Calar: | Grav |
| For 30/20 Tritona). 616 3 inch HE, MAZAT Projectile, Let KC-5: Density, gm/cc Chorge Wt, lb Tetal Me, of Fragments: For TNT For Subject NE Leeding Density: gm/cc 1.71 Inagment Velocity: ft/sec Ar 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Leeding Density: gm/cc 1.71 Storage: Method Dry Hazard Class (Quantity-Distance) Class 9 Compatibility Group Group I Fook Pressure A psi Catenary 25.¼ Impulse NFOC Pendulum 19.8 Energy Leeding Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method None Exudation None Exudation None Exudation None Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method of Lending: Cast Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Storage: Method Dry Leading Density: gm/cc 1.71 Leading Den | For Composition B | 99 8 | 1 | 0129 |
| Density, gm/cc Charge Wt, lb Tatal Me, of Fragments: For TNT For Subject his Leeding Density: gm/cc 1.71 Ingunent Velocity: ft/sec AP 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Method Dry Method Dry Ale: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.6 Energy Alr, Centined: Impulse Under Water: Peak Pressure Impulse Under Water: Peak Pressure Impulse Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse | For Subject HE For 80/20 Tritonal | | Principal Uses: | HE charge |
| Charge Wt, Ib Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc 1.71 Inequant Velocity: ft/sec Ar 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Method Dry Method Dry Method Dry Ale: 3.25" diameter sphere Peok Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Ale, Confined: Impulse Under Water: Peok Pressure Impulse Under Water: Peok Pressure Impulse Underground: Peok Pressure Impulse | 3 inch HE, MAZAT Projectile, Let KC-5: | | • | |
| Tatel No. of Fragments: For TNT For Subject his Leading Density: gm/cc 1.71 Fragment Velocity: ft/sec Ar 9 ft Ar 25½ ft Density, gm/cc Method Dry Hazord Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Air, Coefined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse | Density, gm/cc | | [| |
| For TNT For Subject his Leeding Density: gm/cc 1.71 regulated Velocity: ft/sec Ar 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Maxord Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 impulse NFOC Pendulum 19.8 Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse | Charge Wt, Ib | | | |
| Leeding Density: gm/cc 1.71 regement Velocity: ft/sec At 9 ft At 251/2 ft Density, gm/cc Method Dry Hazord Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Peak Pressure Impulse | • | | Method of Londing: | Cast |
| At 9 ft At 25½ ft Density, gm/cc Method Dry Method D | For Subject HE | | Leading Density: gm/cc | 1.71 |
| Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure \(\Delta \) psi Catenary Impulse NFOC Pendulum 19.8 Exudation Energy Air, Centined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse | At 9 ft | | - Change | |
| Method Dry Hazard Class (Quantity-Distance) Class 9 Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse | | | 3.000 | |
| Air: 3.25" diameter sphere Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse | Density, grit/cc | | Method | Dry |
| Peak Pressure A psi Catenary 25.4 Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | lieut (Relative to TNT); | (a) | Hazard Class (Quantity-Distance) | člass 9 |
| Impulse NFOC Pendulum 19.8 Exudation None Energy Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | Air: 3.25" diameter sphere | | Compatibility Group | Group I |
| Energy Air, Confined: Irnpulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | Peck Pressure & psi Catenary | - | _ | |
| Air, Cenfined: Irripulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | impulse NFOC Pendulum | 19.8 | Exudation | None |
| Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | Energy | | | |
| Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | | | | |
| Underground: Peak Pressure Impulse | • | | | |
| Underground: Peak Pressure Impulse | Impulse | | | |
| Peak Pressure Impulse | Energy | | | |
| | | | | |
| Energy | Impulse | | | |
| | Energy | | 1 | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Effect of Altitude, Charge Diameter and Degree of Confinement on Det mation Velocity*

| (B | ef | er | en | ce | e) |
|----|----|----|----|----|----|
| | | | | | |

| | i | One-Inc | h Column | Two-In | ch Column |
|------------------------|--------------------------|-----------------|-------------------|-----------------|-------------------|
| Explosive | Simulated Altitude, Feet | Confined m/s | Unconfined m/s | Confined m/s | Unconfined m/s |
| TNT, | Ground | 6820 | 6720 | 6670 | 5270 |
| density, gm/cc 1.59 | 30,000 | 666u | 6930(2) | 6610 | 6760(4) |
| | 60,000 | 6800 | . • | 6520 | 6400(4) |
| | 90,000 | 6810 | 6720 | 6550 | 6610(1) |
| Average | | 6798 | 6790 | 6588 | 6260 |
| в-6, | Ground | 7190 | 7360 | 7340 | 6870 |
| density, gm/cc 1.69 | . 30,000 | 7300(2) | 7430 | 7360 | 7980 |
| <u> </u> | 60,000 | 7280 | 7490 | 7550 | 7010 |
| | 90,000 | 7300(3) | 7270 | 7500 | 7000 |
| Average | | 7268 | 7385 | 7438 | 7215 |

^{*}Confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocities at Various Altitudes* (e)

| | | Sir | mulated Alt | tude, Feet | |
|------------------------|----------------------------|---------------|---------------|---------------|---------------|
| Explosive | Charge Diameter, Inches | Ground m/s | 30,000 m/s | 60,000 m/s | 90,000 m/s |
| TRT, | 1 | 2940 | 2991 | 3119 | 2868 |
| density, gm/cc 1.51 | 2 | 3623 | 4191 | 5077 | 4980 |
| н-6, | 1 | 346 1 | 3405 | 3467 | 5563 |
| density, gm/cc 1.71 | 2 | 4603 | 4726 | 499 8 | 5288 |

^{*}Outside diameter 2.54"; inside *tameter 2.04"; length 7".

References:

See HEX-1; HEX-3 reference list.

Haleite (Ethylene Dinitramine) (EDMA)

(In recognition of its development as a military explosive by the late Dr. G. C. ...le of Picatinny Arsenal.)

| Composition: | No. | Molecular Weight: (C2H6114C4) | 150 |
|--|--------------------------|---|--------------|
| | - N _ NO ² | Oxygen Balence: CO ₂ % CO % | -32 -10.5 |
| N 37·3 | π | Density: gm/cc Crystal | 1.71 |
| 0 42.7 н _э с | N NO ^S | Melting Point: "C Decomposes | 175+ |
| C/H Ratio 0.066 | Н | Freezing Point: "C | |
| Impact Sensit' by, 2 Kg Wt: | cm 48 | Boiling Point: °C | |
| Bureau of ines Apparatus, Sample Wt 20 mg Picatinny Arsenal Apparatus Sample Wt, mg | | Refractive Index, no | |
| Friction Pendulum Test: Steel Shoe Fiber Shoe | Unaffected Unaffected | Vecuum Stability Test: cc/40 Hrs, at 90°C | |
| Rifle Bulict Impact Test: Tr | rials | 100°C | 0.5 1.5 |
| | % | 135°C | *• <i>y</i> |
| | o io | 150°C | 11+ |
| - | io 10 | | |
| _ | 0 | 200 Grem Bomb Sand Test: Sand, gm | 52.3 |
| Explosion Temperature: Seconds, 0.1 (no cap used) 1 5 Decomposes | °C 265 216 189 | Sensitivity to Initiation: Minimum Detonating Charge, gri Mercury Fulminate Lead Azide | 0.21 0.13 |
| 10 | 178 | Tetryl | •• |
| 15 | 173 | Bellistic Morter, % TNT: (a) | 100 |
| 20 | 170 | Bellistic Morter, % TNT: (a) Trauzi Test, % TNT: (b) | 139 |
| 75°C Internetional Heat Test: % Loss in 48 Hrs | 0.01 | Plate Dent Test: (c) Method | Α |
| 150°C First Test: | | Condition | Pressed |
| % Loss, 1st 48 Hrs | 0.2 | Confined | Yes |
| % Loss, 2nd 48 Hrs | 0.3 | Density, gm/cc | 1.50 |
| Explosion in 100 Hrs | None | Brisance, % TNT | 122 |
| Flon mobility Index: | 138 | Detonation Rate: Cunfinement | Unconfined |
| Hygrescepicity: % | 0.01 | Condition Charge Diameter, in. | Pressed |
| Voletility: | Ni 1 | Density, gm/cc Rate, meters/second | 1.49 7570 |

Haleite (Ethylene Dinitarine) (EDNA)

| Booster Sensitivity Test: Condition | (d) P re ssed | Decomposition Equation: (e) Oxygen, atoms/sec 10 ^{12.8} 10 | e) 12.1 (f) 1011.1 | | |
|---|-------------------------|---|--------------------------|--|--|
| Tetryi, grn | 100 | (Z/sec) | | | |
| Wax, in. for 50% Detonation | 2.09 | Heat, kilocalorie/mole 30+5 37 (AH, kcol/mci) | .3 30.8 | | |
| Wax, gm | | 1 | - 144-16k [,] | | |
| Density, gm/cc | 1.42 | Phase Liquid So | lid Solid | | |
| Hast of: | | Armor Plate Impact Test: | | | |
| Combustion, cal/gm | 2477 | | | | |
| Explosion, cal/çm | 1276 | 60 mm Morter Projectile: | | | |
| Gas Volume, cc/gm | 90 8 | 50% Inert, Velocity, ft/sec | | | |
| Formation, cal/gm | 134 | Aluminum Fineness | | | |
| Fusion, cal/gr: | | 500-lb General Purpose Bombs: | | | |
| Specific Heat: cal/gm/°C | | Plate Thickness, inches | | | |
| | | · | | | |
| | | 1 | | | |
| | | 11/4 | | | |
| | | 11/2 | | | |
| | | 13 ₄ | | | |
| Burning Rate: cm/sec | | | | | |
| | | Bomb Drop Test: | | | |
| Thermal Conductivity: col/sec/crn/*C | | 17, 2000-16 Semi-Armor-Piercing Bemb vs Concrete: | | | |
| Coefficient of Expension: | | Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: | | | |
| Linear, %/°C | | | | | |
| Volume, %/°C | | Height, ft | | | |
| | | Trials | | | |
| Hardmas, Moha' Scale: | | Unaffected | | | |
| Yaura'a Madulus | | Low Order | | | |
| Young's Modulus: E', dynes/cm² | | High Order | | | |
| E , dynes/cm ² E. Ib/inch ² | | | | | |
| Density, gm/cc | | 1000-lb General Purpose Bomb vs Conc | rete: | | |
| - charty, gray ac | | Height, ft | | | |
| Compressive Strength: Ib/inch² | | Trials | | | |
| | | Unaffected | | | |
| Vapor Pressure: *C mm Mercury | | Low Order | | | |
| | | High Order | | | |
| , | | - ngr order | | | |
| | | | | | |

Haleite (kthylene Dinitramine) (EDKA)

| Fregmentation Test: | Shoped Charge Effectiveness, TNT = | 100: |
|---|--|-------------------|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc 1.61 Charge Wt, ib | Glass Cones Steel Hole Volume Hole Depth | Cones |
| Total No. of Fragments: For TNT | Color: | White |
| For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: 25/5 Haleite/wax Density, gm/cc 1.56 Charge Wt, Ib | Principal Uson: | Booster |
| Total No. of Fragments: For TNT 514 For Subject HE 600 | Method of Looding: | Pressed |
| Fragment Velocity: ft/sec At 9 ft At 251/2 ft Density, gm/cc | Leeding Dentity: gm/cc pai x 5 10 12 15 1.28 1.38 1.41 1.44 Storage: | 20 1.49 Dry |
| Start (Relative to TNT): Air: Pouk Pressuro Impulse Energy: | Hazard Class (Quantity-Distance) Compatibility Group Exudation | Class 9 |
| Air, Confined: Impulse | | |
| Under Weter: Peok Tessure Impulse Energy | | |
| Underground: Peak Pressure Impulse | | |
| Energy | | |
| | | |

Compatibility with Metals:

<u>Dry</u> - Copper, brass, aluminum, mild steel, stainless steel, mild steel coated with acidproof black paint, and mild steel plated with copper nickel, cadmium or zinc are unaffected. Nagnesium and magnesium-aluminum alloy are slightly affected.

<u>Wet</u> - Copper, brass, mild steel coated with acid-proof black paint, and mild steel plated with copper, cadmium, nickel or zinc are heavily corroded. Aluminum is slightly affected and stainless steel is unaffected.

Impact Sensitivities of Various Crystal Habits:

Bureau of Mines Impact Test; 2 Kg Wt:

| Habit | <u>cm</u> |
|------------|-----------|
| lst plate | 55 |
| 2nd plate | 55 |
| Bi-pyremid | 'n |
| Bracydome | 66 |
| Sphenoid | 46 |

Solubility: gm/100 gm (\$) of:

| Water | | <u>A1</u> | coho? |
|-------|-------------------|-----------|-------|
| °c | £ | °c | 2 |
| 20 | 0.25 | 20 | 1.00 |
| 40 | 0.75 | 40 | 2.46 |
| 60 | 2.13 | 60 | 5.22 |
| 80 | 6. 3 8 | 78 | 10.4 |
| 100 | >20 | - | |

Preparation:

(Summary Technical Report of the NDRC, Div 8, Vol 1)

$$\begin{array}{c} \operatorname{CH_2O} + \operatorname{HCN} \longrightarrow \operatorname{Ho} \operatorname{CH_2CN} \\ (98\% \ \operatorname{yield}) \\ \operatorname{Ho} \operatorname{CH_2CN} + \operatorname{NH_3} \longrightarrow \operatorname{NH_2CH_2CN} + \operatorname{H_2O} \\ (82\% \ \operatorname{yield}) \\ \operatorname{NH_2CH_2CN} + \operatorname{2H_2} \longrightarrow \operatorname{H_2N} \operatorname{CH_2CH_2NH_2} \\ (88\% \ \operatorname{yield}) \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \operatorname{CH_2} \longrightarrow \operatorname{NH_2} \\ \end{array}$$

Haleite (Ethylene Dinitramine) (EDNA)

$$\begin{array}{c}
\text{CH}_2 - \text{NH} \\
\text{CH}_2 - \text{NH} - \text{NO}_2 \\
\text{CH}_2 - \text{NH} - \text{NO}_2
\end{array}$$

$$\begin{array}{c}
\text{CH}_2 - \text{N} - \text{NO}_2 \\
\text{CH}_2 - \text{N} - \text{NO}_2
\end{array}$$

$$\begin{array}{c}
\text{CH}_2 - \text{N} - \text{NO}_2 \\
\text{CH}_2 - \text{N} - \text{NO}_2
\end{array}$$

$$\begin{array}{c}
\text{CH}_2 - \text{N} - \text{NO}_2 \\
\text{CH}_2 - \text{N} - \text{NO}_2
\end{array}$$

The raw materials used in this process are cheap and available; the first three reactions proceed smoothly, rapidly and in good yield (70% overall), and only the third requires high pressures. The reaction of ethylenediamine with carbon dioxide at about 220°C and 820 atmospheres has been worked out and is more satisfactory for the preparation of ethyleneurea than the use of chlorethyl carbonate or urea and better than the reaction of acetic anhydride and ethylenediamine to yield N,N'-diacetyl-ethylenediamine which can be treated in a way similar to the above to yield Haleite.

Ethyleneures is very easily nitrated, with strong nitric acid (98%), at ordinary temperature, and in a very short time, and the dinitroethyleneures produced appears to appears, yielding Haleite, immediately after solution in water at 95° C. Both the nitration and hydroly-is are practically quantitative.

Origin:

First described in 1877 by Franchimont and Klotbie (Rec trav chim 7, 17 and 244) but it was 1935 before its value as an explosive was recognized. Standardized during World War II as a military explosive.

Destruction by Chemical Decomposition:

Haleite is decomposed by addition to hot, dilute sulfuric acid. Nitrous oxide, acetaldehyde and othylene glycol are evolved. Haleite is also decomposed by addition to 5 times its weight of 20% sodium hydroxide.

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (t) Report AC-2983/Org Ex 179.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) R. J. Finkelstein and G. Gemow, <u>Theory of the Detonation Process</u>, NAVORD Report No. 90-46, 20 April 1947.
- (f) M. A. Cook and M. Taylor Abbeg, "Isothermal Decomposition of Explosives." University of Utah, Ind Eng Chem (June 1956) pp. 1090-1095.

³³⁵ee footnote 1, page 10.

Haleite (Ethylene Dinitramine) (EDNA)

| Composition: | | Melecular Weight: | 102 |
|---|----------------------------|---------------------------------------|--------|
| % RDX 40 | | Oxygen Belence: | , |
| TNT 38 | | CO, % | -68 |
| Aluminum 17 | | CO % | -35 |
| D-2 Wex 5 | | Density: gm/cc Cast | 1.72 |
| Calcium Chloride, | | Malting Print: 'C | |
| added 0.5 C/H Ratio | | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: | | Boiling Point: °C | |
| Bureau of Mines /\pparatus, cm Sample Wt 20 mg | | Refrective Index, nº | |
| Picatinny Arsenal Apparatus, in. | 16 | n _m | |
| Sample Wt, mg | 21 | nº | |
| Friction Pendulum Test: (b) | | | (a, b) |
| Steel Shoe | Unsffected | Vecuum Stubility Test: cc/40 Hrs, at | (■, 0) |
| Fiber Shoe | | 90°C | |
| | | — 100°C | 0.47 |
| Rifle Bullet Impect Test: Trials | (b) | 120°C | 0.98 |
| % 5 | | 135°C | |
| Explosions 73 | | 150°C | 11+ |
| Partials Burned | | 200 Green Bomb Send Test: | |
| Unaffected 28 | | Sand, gm | 48.1 |
| Explosion Temperature: 'C | (a) | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) | | Minimum Detonating Charge, gm | |
| 1 | | Mersury Fulminate | •••• |
| 5 480 | | Leod Azide | 0.20 |
| 10 | | Tetryl | 0.10 |
| 15 20 | | Bellistic Morter, % TNT: (d) | 133 |
| | | Treuzi Test, % TNT: | |
| 75°C Internation at Test: % Loss in 48's and | | Plate Dent Test: Method | |
| 100°C Heat Test: | (b) | Condition | |
| % Loss, 1st 48 Hrs | 0.05 8 | Confined | |
| % Loss, 2nd 48 Hrs | 0.00 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| | | Detenation Rate: | (a, b) |
| Flommobility Index: | | Confinement | None |
| 0- | | Condition | Cast |
| Hygrescepicity: % 30°C, 95% RH, 7.°C, 95% RH, | 7 days 2.98 7 days 1.13 | Charge Diameter, in. | 1.0 |
| | i days 1.13 | Density, gm/cc | 1.69 |
| Veletility: | | - | 7224 |

| Posster Sensitivity Test: Condition | (c) Cast | Decomposition Equation: Oxygen, atoms/sec |
|---|--------------------------------|---|
| Tetryl, gm | 100 | (Z/sec) |
| Wax, in. for 50% Detanation | 1.25 | Heat, kilocalorie/mole (AH, kca mol) |
| Wax, gm | | Temperature Range, °C |
| Density, gm/cc | 1.73 | Phase |
| Meet of: Combustion, cal/gm | (b) 3882 | Armor Plate Impact Test: |
| Explosion, cai/gm | 91 9 | AR Marker Berlandik. |
| Gas Volume, cc/gm | | 50 mm Morter Projectile: 50% Inert, Velocity, ft/sec |
| Formation, cal/gm | 758 | Aluminum Fineness |
| Fusion, col/am 78°C | 9.25 | - Herricians - Francise |
| | | 500-lb General Purpose Bamba: |
| Specific Heat: cal/gm/°C | (b) | |
| 30°C | 0.249 | Plate Thickness, inches |
| 50 ^o c | 0.264 | 1 |
| ,-0 | V120- | 114 |
| | | 11/2 |
| | | 134 |
| cm/sec Thermal Conductivity: cal/sec/cm/°C 35°C | (b) 0.97 x 10 ⁻³ | Bomb Drop Test: |
| cal/sec/cm/°C 35°C | 0.97 x 10 3 | T7, 2000-16 Semi Armor-Piercing Bomb vs Concrete: |
| Coefficient of Expansion: Lingar, &LAnch | (b) | Max Safe Drop, ft 500-lb General Purpose Bomb vs Concrete: |
| 0°C 35°C | 46 x 10-4 | Source Control Purpose Some VS Controle: |
| 35°C 70°C | 95 × 10 ⁻¹⁴ | Height, ft |
| 100 | 1/7 7 10 | Trials |
| Herdness, Mohs' Scale: | | Unaffected |
| | | Low Order |
| Young's Medulus: | (p) | High Order |
| E', dynes/cm² | 10.3 x 10 ⁹ | Tight Growt |
| E, lb/inch² | 1.49 x 10 ⁻⁵ | 1000-lb General Purpose Bomt vs Concrete: |
| Density, gm/cc | 1.69 | |
| Companying Strength, th /i-ch2 | See below | Height, ft |
| Compressive Strength: Ib/inch ² | Dee Delow | Trials |
| | | Unaffected |
| Vapor Pressure: | | Low Order |
| *C mm Mercury | (b) | High Order |
| Compressive Strength: lt/inch2 | 1303 1.69 | |
| Density, gm/cc | | |

| Fragmuntation Test: | (p) | Shaped Charge Effectiveness, TNT = | 90: |
|--|-----------------|------------------------------------|-----------|
| 90 mm ME, M71 Projectile, Let EGS-1- | -17: | Glass Cones Steel | Cones |
| Density, gm/cc | | Hale Volume | |
| Charge Wt, Ib | | Hole Depth | |
| Total No. of Fragments: | | Celer: | Gray |
| For Composition B | 99 8 | | (ray |
| For Subject HE For 80/20 Tritonal | 910 616 | Principal Uses: | HE charge |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | | |
| Density, gm/cc | | | |
| Charge Wt, Ib | | | |
| Total No. of Fragments: For TNT | | Method of Looding: | Cast |
| For Subject HE | | Leading Density: gm/cc | 1.69 |
| Fragment Velocity: ft/sec | | | 1.09 |
| At 9 ft At 25½ ft | | Storage: | |
| Density, gm/cc | | Method | Dry |
| | | | |
| liest (Relative to TNT): | (e) | Hozard Class (Quantity-Distance) | Class 9 |
| Air: 3.25" diameter sphere Peak Pressure & psi Catenary | 24.7 | Compatibility Group | Group I |
| Impulse NFOC Pendulum | 19.6 | Exudation | None |
| Energy | **** | | · · · |
| Air, Confined: Impulse | | | |
| Under Weter: Peak Pressure | | | |
| Impulse | | 1 | |
| Energy | | | |
| Underground: Peak Pressure | | | |
| Impulse | | 1 | |
| Energy | | i | |
| - , | | | |
| | | | |
| | | 1 | |
| | | | |
| | | | |

| Composition: | | Molecular Weight: | 64 |
|--|-------------|--|----------------|
| RDX 31 | | Oxygen Belence: | |
| TNT 29 | | CO, % | -75 |
| Aluminum 35 | | CO % | -49 |
| D-2 Wax 5 | | Density: gm/cc Cast | 1.84 |
| Calcium Chloride, added 0.5 | | Melting Point: 'C | |
| C/H Ratio | | Freezing Peint: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | | Boiling Point: *C | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | 15 23 | Refrective Index, no no no | |
| Friction Pendulum Test: | | Vocuum Stability Test: | (a, b) |
| Steel Shoe | Unaffected | cc/40 Hrs, at | (=, 0, |
| Fiber Shae | | 90°C | **** |
| Rifle Bullet Impret Test: Trials | (b) | — 100°C | 0.45 |
| | (5) | 120°C | |
| Explosions 78 | | 135°C | |
| Partials | | 150°C | |
| Burned | | 200 Grem Bomb Sand Test: | (b) |
| Unaffected 22 | | Sand, gm | 44.9 |
| Explosion Temperature: °C Seconds, 0.1 (no cap used) | (a) | Sensitivity to Initiation: Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 500 |) | Lead Azide | 0.20 |
| 10 | | Tetryl | 0.10 |
| 15 20 | | Ballistic Morter, % TNT: (d) | 111 |
| | | Troug Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | | Piete Dent Test: Method | |
| 167°C Heat Test: | (b) | Condition | |
| % Loss, 1st 48 Hrs | 0.70 | Confined | |
| % Loss, 2nd 48 Hrs | 0.00 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| Flammebility Index: | | Detenation Rate: Confinement | (a, b) None |
| Hye peconicity: % 30°C, 95% RH. | 7 days 2.01 | — Condition | Cast |
| Hygroscopicity: % 30°C, 95% RH. (b) 71°C, 95% RH. | 7 days 0.31 | Charge Diameter, in. | 1.0 |
| Voletility: | | Density, gm/cc | 1.81 |
| v www.ratv: | | Rate, meters/second | 6917 |

| Bosster Sensitivity Test: Condition | | Decemposition Equation: Oxygen, atoms/sec |
|--|--------------------------------|---|
| Tetryl, gm | | (Z/sec) |
| Wax, in. for 50% Detonation | | Heat, kilocalorie/mole |
| Wax, gm | | (ΔH, kcol/mol) Temperature Range, °C |
| Density, gm/cc | | Phase |
| | | |
| Heat of: Combustion, cal/gm | (b) 14495 | Armor Plate Impact Test: |
| Explosion, cal/gm | 877 | 60 mm Morter Projectile: |
| Gas Valume, cc/gm | | 50% Inert, Velocity, ft/sec |
| Formation, cal/gm | 491 | Aluminum Fineness |
| Fusion, cal/gm | 9 . 30 | |
| | | 500-lb General Purpose Bembs: |
| Specific Hust: cal/gm/*C | | |
| 30°c | 0.254 | Plate Thickness, inches |
| 5 0 ° შ | 0.254 | 1 |
| | | 134 |
| | | 11/2 |
| | | 134 |
| Burning Rate: | | |
| cm/sec | | Bomb Drop Test: |
| Thermel Conductivity: cal/sec/cm/*C 35°C | (b) 1.70 x 10 ⁻³ | T7, 2000-lb Semi-Armor-Piercing Semb vs Concrete: |
| Coefficient of Expension: | (b) | Max Safe Drop, ft |
| Linear, Al/Inch | 40 x 10 ⁻⁴ | 500-lb General Purpose Bomb vs Concrete: |
| 0°C 35°C | 63 x 10 ⁻¹ | _ |
| 70°C | 130 x 10 | Height, ft |
| Mandage Maked Control | | Trials |
| Hardness, Mehe' Scale: | | Unaffected |
| Young's Modulus: | (b) | Low Order |
| E', dynes/cm² | 11.5 x 10 ⁹ | High Order |
| E, Ib/inch² | 1.67 x 10 ⁵ | 1000 th General Promose Possibles Commission |
| Density, gm/cc | 1.81 | 1000-ib General Purpose Bomb vs Concrete: |
| | | Height, ft |
| Compressive Strength: Ib/inch ² | See below | Trials |
| | | Unaffected |
| Vapor Pressure: | | Low Order |
| °C mm Mercury | | High Order |
| | | |
| | 1610 | |
| imm Mercury impressive Strength: 1b/inch ² Density, gm/cc Ultimate deformation. 5 | 1610 1.61 1.37 | |

| regmentation Test: | | Shaped Charge Effectiveness, TNT = | 100: |
|---|--------------------|------------------------------------|-----------|
| 90 mm HE, M71 Projectile, Let EGS-1- | 17: | Gloss Cones Steel | Cones |
| Density, gm/cc | | Hole Volume | |
| Charge Wt, Ib | | Hole Depth | |
| Total No. of Fragments: | | Color: | |
| For Composition B | 99 8 | Color: | Gra; |
| For Subject HE For 80/20 Tritonal | 476 61 6 | Principal Uses: | HE charge |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | | |
| Density, gm/cc | | J | |
| Charge Wt, Ib | | | |
| Total No. of Fragments: | | Method of Leading: | Chat |
| For TNT For Subject HE | | | |
| | | Leading Density: gm/cc | 1.81 |
| regment Velocity: ft/sec At 9 ft | | | |
| At 25½ ft | | Storage: | |
| Density, gm/cc | | Method | Dry |
| est (Relative to TNT): | (a) | Hazard Class (Quantity-Distance) | Class 9 |
| Air: 3.25" diameter sphere Peak Pressure A psi Catenary | 25.5 | Compatibility Group | Group I |
| Impulse NFOC Pendulum | 20. 6 | Exudation | None |
| Cnergy | | | |
| Ale, Confined: | 4. | | |
| Impulse | _ | 1 | |
| Under Weter: Peak Pressure | • | | |
| Impulse | | 1 | |
| Energy | | | |
| Underground: Pook Pressure | | 1 | |
| Impulse | : | | |
| Energy | | | |
| | | | |
| | | | |
| | | | |

HBX-1; HBX-3

The Stability of HBX Compositions Made With and Without Desiccants and Containing Added Moisture *

| | Moisture, | Acidity, | 100°C Vac | | Hygrosco | picity, 🖇 |
|-----------------------|-----------|---------------|-----------|-------|----------|-----------|
| Explosive | 2 | <u> </u> | CC gas | Hours | 959 | RH |
| Composition | | | | | 30°C | 71°C |
| Standard HBX-1 | 0.73 | 0.011 | 0.47 | 40 | +2.98 | +1.13 |
| +0.2% moisture | · | | 0.68 | 40 | | |
| +0.4% moisture | ! | • | 0.62 | 40 | | |
| +0.6% moiscure | ; | <u>!</u> · | 0.50 | 40 | | |
| HBX-1 without CaCl | 0.00 | 0.029 | 0.36 | 40 | -0.06 | -0.25 |
| +0.2% moisture | | | 0.25 | 40 | | |
| +0.4% moisture | | | 0.23 | 40 | | |
| +0.6% moisture | | : | 0.27 | 40 | | |
| HBX-1 with silica gel | 0.06 | 0.031 | 0.73 | 40 | +0.08 | +0.04 |
| Standard HBX-3 | 0.54 | 0.012 | 0.45 | 40 | +2.01 | +0.31 |
| +0.2% moisture | 0.,,4 | 1 0.012 | 0.47 | 40 | | .0. |
| +0.4% moisture | | | 0.43 | 40 | | |
| +0.6% moisture | | | 0.41 | 40 | | |
| HEX-3 without CaCl | 0.02 | 0.049 | 0.46 | 40 | -0.06 | -0.29 |
| +0.2% moisture | | | 0.26 | 40 | | |
| +0.4% moisture | | | 0.26 | 40 | | |
| +0.6% moisture | | | 0.20 | 40 | | |
| HRX-3 with silica gel | 0.04 | 0.100 | 0.45 | 40 | +0.09 | +0.05 |
| Standard N-6 | 0.71 | 0.017 | 0.47 | 40 | +2.01 | +1.77 |
| +0.2% moisture | 0.11 | 0.01 | 0.88 | 40 | 72.01 | AT+11 |
| +0.4% moisture | | | 0.63 | 40 | | |
| +0.6% moisture | | | 0.65 | 40 | | , |
| H-6 without CaCl | 0.03 | 0.082 | 0.10 | 40 | -0.06 | -0.25 |
| +0.2% moisture | | | 0.10 | 40 | | |
| +0.4% moisture | | | ა.25 | 40 | | |
| +0.5% moisture | | | 0.23 | 40 | | |
| H-6 with silics gel | 0.05 | 0.028 | 0.43 | 40 | +0.09 | +0.06 |

^{*} All samples were ground to 20/100 mesh size, 7 days before tests. Silica gel used was Fisher Mentific Company, Lot 541492, through 100 mesh U. S. Standard Sieve.

HBX-1; HBX-3

Preparation:

HBX explosive mixtures are prepared by melting TNT in a steam-jacketed melt kettle equipped with a mechanical stirrer. Water-wet LDX is added slowly with stirring and heating until all the water is evaporated. Aluminum is added, and the composition is stirred until uniform. D-2 wax and calcium chloride are then added. The desensitizer wax, also known as Composition D-2, consists of 64% paraffin and other waxes, 14% nitrocellulose and 2% legithin. The mixture is cooled from approximately 95° to 100°C to a temperature considered suitable for casting (the lowest practicable pour temperature). HBX can also be made by adding the calculated amount of TWT to Composition B to outsin the desired proportion of RDX/TNT. The appropriate weights of the other ingredients are added to complete the mixture.

Origin:

Developed during World War II, as relatively insensitive mixtures, by adding 5% desensitizer to Toroex II, for high blast explosive applications.

- (a) O. E. Sheffield, Blast Properties of Explosives Containing Aluminum or Other Retal Additives, PATR No. 2353, November 1956.
- (b) S. D. Stein, G. J. Horvat and O. E. Sheffield, Some Properties and Characteristics of HBX-1, HBX-3 and H-6, PATR No. 2431, June 1957.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo. 10,303, 15 June 1949.
- (d) S. R. Walton, Report on the Program to Develop an Improved HBX-Type Explosive, MAYORD Report No. 1502, 26 July 1950.
- (e) A. W. O'Brien, Jr., C. W. Plummer. R. P. Woodburn and V. Philipchuk, <u>Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions</u>, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAT-19-020-501-0kD-(P)-58).
- (f) Also see the following Picatinny Arsenal Technical Reports on HBX Explosives: 1756, 2138, 2169.

³⁴See footnote 1, page 10.

HEX-24

| Composition: | | Molscular Weight: | 47.6 |
|---|--------------|-----------------------------|-------------|
| % Potassium Perchlorate | 32 | Oxygen Belence: | ١ |
| (17 microns) | 1.0 | CO: % | -42 |
| Aluminum, atomized (20 microns) | 48 | CO % | - 34 |
| RDX (through 325 mesh) | 16 | Presed of 20,000 psi | 1.39 2.1 |
| Asphaltum (through 100 mesn) | . . . | Meking Point: °C | <u> </u> |
| C/H Ratio | | Freezing Point: *C | |
| Impact Sonsitivity, 2 Kg Wt: | | Beiling Point: 'C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | | Refrective Index, nº | |
| Picatinny Arsenal Apparatus, in. | 16 | nº | |
| Sample Wt, mg | 24 | | |
| | | n‰ | |
| Friction Pendulum Tust: | | Vocuum Stability Test: | |
| Steel Shoe | Detonates | cc/40 Hrs, at | |
| Fiber Shoe | Unaff-cted | 90°C | |
| 200 B Mark 1 200 B T 1 1 | | — 100°C | 1.25 |
| Rifle Bullet Impact Test: Trials | | 120°C | |
| % Explosions | | 135°C | |
| Partials | | 150°C | |
| Burred | | 200 Gram Bomb Sand Test: | |
| Unoffected ` | | Sand, gm | 12.5 |
| | | | |
| Explosion Temperature: °C | | Sensitivity to Initiation: | |
| Seconds, 0.1 1/2 or used) | | Minim Detarating Charge, gm | |
| 1 5 520 | | Mercury Fulminate | |
| , | • | Lead Azide | 0.20 |
| 10 15 | | Tetryl | 0.25 |
| 20 | | Ballistic Morter, % TNT: | |
| | | Trouzi Trot, % TNY: | |
| 75°C International Heat Test: 4 Loss in 46 Hrs | | Platy Dent Test: Method | |
| 100°C Kee? Test: | | Condition | |
| % Loss, 1st 48 Hrs | 0.15 | Confined | |
| % Loss, 1st 46 Firs | 0.00 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| Explosion in 100 mis | - | Detenation Rate: | |
| Flammability Index: | | Confinement | |
| | | Condition | |
| Hygroscopicity: % | None | Charge Diameter, in. | |
| | | Density, gm/cc | |
| Volatilky: | None | Rate, meters/second | |

| Frogmentation Test: | Shaped Charge Effectiveness, TNT = 100: |
|--|---|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones |
| Density, gm/cc | Hole Volume |
| Charge Wt, io | Hole Depth |
| Total No. of Fregments: | |
| For TNT | Color: Gray |
| For Subject HE | |
| 3 inch HE, M42A1 Projectile, Let XC-5: | Principal Uses: HE filler for small caliber projectiles |
| | projecuites |
| Pensity, gm/cc | |
| Charge Wt, Ib | |
| Total No. of Fragments: | Method of Leading: Pregsed |
| For TNT | Trapped. |
| For Subject HE | |
| | Leading Density: gm/cc |
| Fregment Velecity: ft/sec | Pressed at 20,000 psi 2.1 |
| At 9 ft | |
| At 251/ ₅ ft | Storage: |
| Density, gm/cc | Method Dry |
| Heat (Relative to TNT): | Hazard Class (Quantity-Distance) |
| | |
| Aire | Compatibility Group |
| Peak Pressure | Eu desten |
| Impulse | Exudation None |
| Energy | |
| Air, Confined: | Static Tests: |
| Impulse | 20 mm T215El Projectile: PA Peak Pressure, psi 55 |
| · | PA Peak Pressure, psi 55 NFOC 20" Blast Cube 44 |
| Under Water: | APG 24" Blast Cube 44 |
| Peak Pressure | Static Tests: |
| Impulse | 20 mm M97 Projectile: |
| Energy | HEX-24 Tritonal Torpex |
| | Foxboro psi 19 12.4 13.0 |
| Underground: Pack Pressure | Catenary psi 46 Duration, microsec 533 |
| | APG 24" Blast Cube 36 24 32 |
| Impulse Energy | |
| Energy Ov 2552 | Heat of: |
| lame Temperature, OK 2552 | Combustion, CBI/Em 419 |
| ctivation Energy, kcal 20.4 | |
| Temp, C 450 to 570 Specific reaction | Gas volume, ee/gm 179 |
| rate, k 1.64 x 10 ⁻⁵ | 5 |

| Composition: % | | Moleculer Weight: | 47.6 | | |
|--|---------------------|--|------------|--|--|
| Potassium Perchlorat | e 32 | Oxygen Balance: | | | |
| (17 microns) | \ 1.0 | CO. % | -3r -45 | | |
| Aluminum, flaked (1 | | CO % | - 3" | | |
| RDX (through 325 mesh) 16 Asphaltum (through 100 mesh) 4 | | Density: gm/cc Apparent Pressed at 20,000 psi | 9.63 | | |
| | | Melting Point: °C | | | |
| C/h Rotio | | Fruezing Point: °C | | | |
| Impect Sensitivity, 2 Kg Wt: | | Boiling Point: °C | | | |
| Bureau of Mines Appara Sample Wt 20 mg | itus, em | Refractive Index, no | | | |
| Picatinny Arsenal Appa | rotus, in | _ | | | |
| Sample Wt, mg | | n _B | | | |
| | | n ₃₀ | | | |
| Friction Pendulum Test: | | Vacuum Stability Test: | | | |
| Steel Shoe | Partially detonates | cc/40 Hrs, at | | | |
| Fiber Shoe | Unaffected | 90°C | | | |
| Rifle Bullet Impact Test: | Trials | - 100°C | 1.52 | | |
| | % | 120°C | | | |
| Explosions | 70 | 135°C | | | |
| Portiols | | 150°C | | | |
| Burned | | 200 Gram Bomb Sand Test: | | | |
| Unaffected | | Sand, gm | 23.7 | | |
| Explosion Temperature: | ,c | Sensitivity to Initiation: | | | |
| Seconds, 0.1 (no cap us | sed) | Minimum Detonating Charge, gm | | | |
| 1 | *** | Mercury Fulminate | | | |
| 5 | 545 | Lead Azide | 0.20 | | |
| 10 | | Tetryi | 0.25 | | |
| 15 20 | | Ballistic Morter, % TNT: | | | |
| | | Trauzi Test, % TNT: | | | |
| 75°C International Heat To % Loss in 48 Hrs | est: | Plate Dent Test: | | | |
| | | Method | | | |
| 100°C Heat Test: | | Condition | | | |
| % Loss, 1st 48 Hrs | | Confined | | | |
| % Loss, 2nd 48 Hrs | | Density, gm/cc | - | | |
| Explosion in 100 Hrs | | Brisance, % TNT | | | |
| Pa 1 141. 4 4 | | Detonation Rate: | | | |
| Flammability Index: | | Confinement | | | |
| H | | - Condition | | | |
| Hygrescopicity: % | | Charge Diameter, in | | | |
| Valetiča. | | Density, gm/cc | | | |
| Voletility: | | Rate, meters/second | | | |

| Fragmentation Test: | Shaped Charge Fffectiveness, TNT | = 100: |
|--|---|------------------|
| 90 mm HE, M71 Projectile, Lot WC-91: | Glass Cones SI | reel Cones |
| • | Hole Volume | |
| Density, gm/cc | Hole Depth | |
| Charge Wt, Ib | , ioia Dapini | |
| Total No. of Fragments: | Color: | Gray |
| For TNT | | |
| For Subject HE | Principal Uses: HE filler for | small caliber |
| 3 inch HE, M42A1 Projectile, Lot KC-5: | projectiles | |
| Density, gm/cc | | |
| Charge Wt, Ib | | |
| Charge VVI, ID | | |
| Total No. of Fragments: | Method of Looding: | Pressed |
| For TNT |] | |
| For Subject HE | | |
| | Loading Density: gm/cc | 1.62 |
| Fregment Velocity: ft/sec | Pressed at 20,000 | 1.02 |
| At 9 ft | Storage: | |
| At 25½ ft | 30# 05 0. | |
| Density, gm/cc | Method | Dry |
| | | |
| Blast (Relative to TNT): | Hazard Class (Quantity-Distance | (e) |
| | Compatibility Group | |
| Air: Peak Pressure | · · | |
| Impulse | Exudation | None |
| Energy | | |
| Litergy | Static Tests: | |
| Air, Confined: | 20 mm T215El Projectile | |
| Impulse | PA Peak Pressure, ps NFOC 20" Blast Cube | 1 77 45 |
| | APG 24" Blast Cube | 42 |
| Under Water: Peak Pressure | Static Tests: | |
| | 20 mm M97 Projectile: | |
| Impulse | HEX-46 | THT Tetryl |
| Energy | Fostoro psi 17.3 | 2.5 3.5 23 28 |
| Underground: | Duration, microsec 517 | 560 5 30 |
| Peak Pressure | APG 24" Blast Cube 29 | 10 |
| Impulse | | |
| Energy | Heat of: | , 3.3.5 |
| Flame lemperature, % 23"2 | | 4119 1735 |
| Activation merg. kent 25. | es Volume, no one | 200 |
| lemp. 4,0 to 40 | | |
| Specific resction | -· | |
| rate, k | | |

Cook-Off Tests:

20 mm T215E1 HEY-48 Loaded Projectiles With Dye-Costed RDX Top-Off

| Projectile No. | Cut-Off Temp. C | Cook-Off |
|----------------|-----------------|-----------|
| 1 | 170 | Yes (198) |
| 2 | 150 | No |
| 3 | 155 | Yes (190) |
| 14 | 150 to 175 | No |

National Northern Projectile Load:

(c)

| MOX-2B (no top-off) | 195 |
|--------------------------------|-----|
| MOX-2B (Tetryl top-off) | 150 |
| MOX-2B (97/3, RDX/wax top-off) | 175 |
| MOX-2 (no top-off) | 175 |

(c)

Fragment Penetration Tests:

| | | | Avg. No. of Penetrations per Round in Zone 550-1300 | | |
|------------|-------------------|----------------|--|--------|-------------|
| Projectile | Filler | Altitude, Feet | 0.020" | 0.040" | 0.051" |
| T215E1 | ਸਾਫ਼ x −48 | Ground | 352 | 264 | 282 |
| | : : | 60,000 | 676 | 432 | 388 |
| 1282E1 | MOX-2B | Ground | 634 | 290 | 235 |
| | | 60,000 | 807 | 367 | 250 |
| EX8 Mod 0 | MOX-2B | Ground | 476 | 268 | 224 |
| | | 60,000 | 672 | 264 | 25 6 |

The fragment penetration test records numbers of complete penetrations of aluminum panels of various thicknesses at 2.5 feet from the static detonation. The total penetrations recorded on the 24ST-3 aluminum panels occurred with the projectile nose always pointed toward ${\rm C}^{\rm O}$ and the base toward ${\rm 180}^{\rm O}$.

The test data indicate that on the thicker panels, 0.040" and 0.051," the KEX-48 loaded T215E1 projectile produced more comple e fragment penetrations at ground and altitude than MOX-2B loaded T282E1 and EX8 Mod 0 projectiles.

HEX-24; HEX-48

Preparation:

The HEX compositions were prepared by blending the appropriate weight of the dry ingredients in a Patterson-Kelly twin-shell blender for at least 30 minutes.

In alternate procedure for 100 to 200 gram batches used a "Cradle-Roll" mixing device. This device consisted of a half-barrel type container constructed of wood and lined with an electrical conductive material. A plastic roll was allowed to move over the ingredients by remote control action of the container. The roll action prevented caking of the mix but had no adverse effect on the particle size of the ingredients. The period of time required to obtained a uniform and intimate mixture was approximately fifteen minutes.

Origin:

The development of "slow-burning" explosive mixtures which would produce increased blast effects in enclosed or nearly enclosed spaces directed attention to their use for possible military application. In 1950 Picatinny Arsenal developed a high capacity filler for 20mm projectiles consisting of 85/10/5 RDX/aluminum/desensitizer which was more powerful than standard tetryl filler. However, in comparison with MOX type explosives, there was little doubt as to the superior performance of the MOX mixture. HEX (high prergy explosive) mixtures were developed at Picatinny Arsenal in 1953 (Ref a) as superior high big to compositions suitable for use in small caliber projectiles.

- (a) O. E. Sheffield and E. J. Murray, <u>Development of Explosives—Metallized Explosives—High Blast Fillers for Smell Caliber Shell</u>, <u>Picatinny Arsen 1 Memorandum Report No. MR-49</u>, <u>21 December 1953</u>.
- (b) O. E. Sheffield, <u>Properties of MOX-Type Explosive Mixtures</u>, PATR No. 2205, October 1955.
- (c) National Northern Corporation, Letter from Dr. C. M. Saffer, Jr., to Commanding Officer, Picatinny Arsenal, 12 June 195%

³⁵See footnote 1, page 10.

2.4,0.2',1',6'-Hexanitro-oxanilide (EMC)

| Composition: | Molecular Weight: $(C_{14}H_6H_2C_{14})$ | |
|--|--|----------------|
| c 33.0 | Oxygen Balance: CO ₂ % CO % | -53.4 - 9.4 |
| H 1.2 NH NH | Density: gm/cc | |
| N 21.9 C ₂ N | Melting Point: 'C Decomposes | 302 |
| 0 43.9 | Freezing Point: 'C | |
| Impact Sensitivity, 2 Kg Wt: | Boiling Point: 'C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | Refractive Index, no | |
| Picatinny Arsenal Apparatus, in. 15 | n ₂₃ | |
| Sample Wt, mg 12 | n ₂₀ | |
| Friction Pendulum Test: | Vacuum Stability Test: | |
| Steel Shoe Unaffected | cc/40 Hrs, at | |
| Fiber Shoe Unaffected | 90°C | |
| Riffe Bullet Impact Test: Triais | 100°C | 0.40 |
| % | 120°C | |
| Explosions | 135°C | |
| Partials | 150°C | |
| Burned | 200 Gram Bomb Sand Test: | |
| Unaffected | Sand, gm | 52.1 |
| Explosion Temperature: | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) | Minimum Detonating Charge, gm | |
| 201 | Mercury Fulminate | |
| 5 384 | Lead Azide | 0.30 |
| 10 | Tetryl | 0.25 |
| 15 20 | Ballistic Mortar, % TNT: | |
| | Trauxi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: | |
| | Method | |
| 100°C Heet Test: | Condition | |
| % Loss, 1st 48 Hrs 0.07 | Confined | |
| % Loss, 2nd 48 Hrs 0-05 | Density, gm/cc | |
| Explosion in 100 Hrs None | Brisance, % TNT | |
| Flemmebility Index: | — Detonation Rate: Confinement | |
| remmedity index. | | |
| | Condition Charge Diameter, in | |
| Myerocopicity: % oson and our | | |
| Hygroscopicity: % 25°C, 30% PH 0.1) | Density, gm/cc | |

| Fragmentation Test: | Shaped Charge Effectiveness, Ti | Shaped Charge Effectiveness, TNT = 100: | | |
|--|--|---|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Hole Volume Hole Depth | Steel Cones | | |
| Total No. of Fragments: For TNT | Color: | Almost white | | |
| For Subject HE 3 inch HE, M42A* Projectile, Lot KC-5: Density, gm foc Charge Wt, b Total No. of Fragments: | Principal Uses: Igniter pow composition | s | | |
| For TNT For Subject HE | | Method of Loading: Pressed and extruded | | |
| Fragment Velocity: ft/sec | Loading Density: gm/cc | | | |
| At 9 ft At 25½ ft | Storage: | | | |
| Density, gm/cc | Method | Dry | | |
| Blast (Relative to TNT): | Hazard Class (Quantity-Dista | nce) Class 9 | | |
| Air: Peak Pressure | Compatibility Group | | | |
| Impulse Energy | Exudation | None | | |
| Air, Confined: Impulse | | | | |
| Under Water: Peak Pressure | | | | |
| impulse Energy | | | | |
| Underground: Peak Pressure | | | | |
| Impulse Energy | | | | |
| | | | | |
| | | | | |
| | | | | |

2,4,6,2',4',6'-Hexanitro-oxanilide (HNO)

Solubility in the following substances:

Solvent

<3 gm in 100 cc, at 23° C ~ 5 gm in 100 cc, at 210° C 0.10 gm in 100 cc, at 100° C Ni trobenzene Water Alcohol (Ethyl) Insoluble Acetone Insoluble Benzene Insoluble Butvl acetate Insoluble Carbon tetrachloride Insoluble Dimethylformamide Ether (Ethyl) Very soluble Insoluble Acetic Acid Insoluble Nitric Acid Soluble Crystalline form Long rectangular glistening plates from nitrobenzene

Preparation:

To prepare hexanitro-oxanilide, first prepare tetranitro-oxanilide as described herein under the entry "2,4,2',4'-Tetranitro-oxanilide (TNO)."

A 1.5 liter round bottom flask is equipped with a stirrer of the type which causes a downward swirl. The flask is jacketed for hot and cold water. 187 grams of nitric acid of specific gravity 1.49 (commercial grade) is placed into the flask and 100 grams of sulphuric acid is added to the nitric acid under agitation. The mixed acid is cooled to 10°C. 29.2 grams of tetranitro-oxamilide is slowly added to the mixed acid under rapid agitation maintaining the temperature at 8°-10°C. After the addition of the TNO is completed (approximately 25 minutes) the temperature is raised to 85°C over a period of 2 hours and held at 85°-90°C for one hour. The hexanitro-oxamilide (HNO) "slurry" is filtered on a Fuchrer funnel and purified as explained under "Tetranitro-oxamilide."

Origin:

A. G. Perkin in 1892 obtained hexanitro-oxanilide directly by heating to boiling a solution of tetranitro-oxanilide in a mixture of sulfuric and nitric acids. He also prepared the same compound from oxanilide by the action of a boiling mixture of fuming nitric and sulfuric acids (J Chem Soc $\underline{61}$, 462 (1892)).

- (a) L. Gowen and R. Dwiggens, <u>Case Gun Ignition Studies</u>, NAVORD Report No. 2321, 13 June 1952.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Research Laboratory Report 54-TF1-83, 20 December 1954.
- (c) S. Livingston, Preparation of Tetranitro Carbazole, PA Chemical Research Laboratory Report 136, 330, 11 April 1951.
 - (d) S. Livingston, Development of Improved Ignition Type Powders, PATA No. 2267, July 19 6.

³⁶See footnote 1, page 10.

| Composition: CH ₂ | Melecular Weight: (Cin H8N8O | 296 |
|---|---|--------------|
| c 16.8 02n-h n-nc3 | Oxygen Brinnes: CO ₂ % | <u> </u> |
| H 2.7 H ₂ C CH ₂ | CO % | -21.6 0.0 |
| N 37.9 02N-N N-NO2 | Density: gm/cc Crystal | 1.90 |
| 0 43.2 CH ₂ | Molting Point: *C Capillary a Koffer Micro Bot S | ethod 273 |
| C/H Ratio 0.095 | Freezing Feint: *C | |
| mpact Sanshivity, 2 Kg Wt: | Boiling Point: *C | |
| Bureau of Mines Apparatus, cm 32 Sample Wt 20 mg | Refrective Index, no | <u> </u> |
| Picatinny Arsenal Apparatus, in. 9 | ng | |
| Sample Wt, mg 23 | n _s | |
| Friction Pendulum Test: | | |
| Strei Shoe Explodes | Vocuum Stability Test: | |
| Fiber Shoe Unaffected | 90°C | |
| Rirle Sullet Impact Yest: Trials | 100°C | 0.37 |
| % | 120°C | 0.45 |
| Explosions | 135°C | •• |
| Pertials | 150°C | 0.62 |
| Surred | 200 Gram Bomb Sand Test: | |
| Unaffected | Sand, gm | 60.4 |
| Explication Temperature: *C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cup used) 380 | Minimum Detonating Charge, | j m |
| 5 327 | Mercury Fulminate | |
| 10 306 | Lead Azide | 0.30 |
| 15 | Tetryl | |
| 20 | Ballistic Morter, % TNT: | 150 |
| 75°C International (feat Test: | Trensi Test, % TNT: | 145 |
| % Loss in 48 Hrs | Plate Dent Test: | |
| | Method Condition | |
| 180°C Heat Yest: | Confined | |
| % Loss, 1st 48 Hrs 0.05 % Loss, 2nd 48 Hrs 0.03 | Dencity, gm/cc | |
| 96 Loss, 2nd 48 Hrs 0.03 Explosion in 100 Hrs None | Brisonia 7, 96 TNT | |
| NOTE TO THE NOTE | | |
| Semmobility Index: | Confinement | |
| | Conditiun | |
| Hygrescapicity: % | Charge Diumeter, in. | |
| 30°C, 95% RH (c) 0.00 | Density, gm/cc | 1.64 |
| | | |

beta-HO

| leaster Sensitivity Test | | | Decomposition Equation: | (•)9.7 |
|--|-------------|----------------|------------------------------------|------------------|
| Condition | | | Oxygen, atoms/sec | 10-5. (|
| Tetryl, ym | | | (Z/sec) Heat, kilocaloris/mole | 52.7 |
| Wax, in. for 50% Di | rtonation | ` | (AH, kcol/mal) | • |
| Wax, gm | | | Temperature Ronge, *C | 271-314 |
| Density, gm/cc | | | Phase | Liquid |
| lest of: | | | Armer Plate Impact Test: | |
| Combustion, cal/gm | | 23¢.` | | |
| Explosion, col/gm | (e) | 1356 | 60 mm Morter Projectile: | |
| Gas Voiume, cc/g | | | 50% Inert, Velocity, ft/sec | |
| Formation, cal/gm | (e) | -60.5 | Aluminum Fineness | |
| Fusion, cal/gm | | | | • |
| | | | 500-lb General Purpose Bombe: | |
| posific Heat: cal/gm/ | | stallized (g) | | |
| <u>°c</u> | <u>°с</u> | | Plate Thickness, inches | |
| -75 0.153 | 85 | 0.288 | 1 , | |
| 0 0.228 25 0.243 | 90 100 | 0.290 0.295 | 1 | |
| 50 0.266 | 125 | 0.295 | 1% | |
| 75 0.282 | 150 | 0.315 | 11/2 | |
| · · · · · · · · · · · · · · · · · · · | | - | 1% | |
| Jurning Rate: | • | | | |
| cm/sec | | · | Bearb Drep Test: | |
| Thermal Conductivity: cel/sec/cm/°C | | | 17, 2000-th Semi-Armer-Plercing | Bomb vs Concrete |
| Coefficient of Exponsion | | | Max Sate Drop, ft | |
| Linear, %/°C | •• | | 300-16 General Purpose Bomb vi | Concrete: |
| Volume, %/°C | | | Height, ft | |
| | /-> | | Trials | |
| Krdnar, Mehe' Scale: | (e) | 2.3 | Unaffected | |
| | | | Low Order . | |
| roung's Modulus: | | | High Order | |
| E', dynas/cm ³ | | | | |
| E, It/inch | | | Fuco its Gamerat Purpose Sausis vi | Con croto: |
| Dansity, gm/cc | | | | |
| | | | - Height, ft | |
| Economiative Strangth: I | b/inch* | | Trials | |
| | | | Unaffected | |
| Vapor Proceure: | | | Low Order | |
| | nm Mercury | | High Order | |
| | • | | | |
| | | | } | |
| | | | | |

Two men are required to regulate the addition of reagents and control the temperature during the initial stage addition; one men can complete the procedure. A 1-liter 5-necked flask is used, the center neck for an efficient stirrer, one side neck for a thermometer, and the other necks for burrettes and a gas outlet (to water trap). The flask is placed in a pan with steam and cold water inlets, for temperature control.

Five ec of acetic anhydride and 250 cc glacial acetic acid are poured into the flask and the temperature brought to $45 \pm 1^{\circ}$ C, and held there for the duration of the entire reaction. The reagents (a solution of 33.6 gm hexamine in 55 gm of glacial acetic acid, 100 cc of acetic anhydride ard 40 cc of a solution of 42.3/57.7-ammonium nitrate/98% nitric acid) are then added simultaneously, continuously and equivalently over a 25-minute period. The reaction mixture is aged 15 minutes.

The second stage reagents (60 cc of 42.3/57.7, ammonium nitrate/98% nitric acid and 150 cc acetic anhydride) are then added simultaneously, continuously and equivalently over a 25-minute period. The mixture is aged 65 minutes, poured into 1.5 liter of water and simmered on a steam bath for 12 hours. Cool, filter and dry the RDX-BMX precipitate (yield 73% BMX).

The RDK is destroyed, leaving HMX, as follows: 1025 gm of the crude product are placed in a solution of 15 gm sodium tetraborate decahydrate in 5 liters of water, heated to boiling with agitation, and 5 N RacH added at the rate of 3 cc/min. When about 730 cc have been added the pR increases sharply from a little over 6.7 to over 9.7 which corresponds to complete destruction of the WDM. Filter the HMX from the hot mixture; yield 612 gm, mp 279.50-280.50C. Recrystallization from nitromethane yields material selting at 2610-262°C.

Origin:

Was discovered as an impurity (by-product) in the nitration of hexamethylene-tetramine to form REM. It is now samufactured directly by the process described above and has valuable use in explosive systems.

Removal of RDX from H-X-DTX Mixtures and Recovery of a RDX-HMX Mixture (This procedure appears suitable for use with mixtures containing 80% or more HMX):

Procedure:

500 grams of HMT containing 12.25% RDX are placed in a 1500 cc beaker, 500 cc of acetone is added and the slurry is agitated for several minutes at room temperature. Before complete settling, the RDX-MAX-acctone solution is decanted.

To the residual HMX-RDX, another 500 cc of acetone is added. The slurry is heated on the steambath and while holling, agitated for several minutes. The boiling RDX-HMX-acetone solution is decented. The residual HMV is now washed with cold acetone into a funnel. This HMX is now taken up in 95% alcohol, filtered and dried. Yield 353.9 gm or 70.78%.

All the acetume extracts are combined and evaporated to dryness. Yield 137.5 gm or 26.5%.

Yield Balance:

| Pure HMX obtained - 353.9 gm | 70.78% |
|---|------------------------|
| Total ROX-HAX mixture recovered - | 26.50% |
| Samples taken during process - 2.4 gm Loss during process | 2.24 % 2.48% |
| Total | 100.00% |

Various samples were analyzed for RXD content:

| ı. | Crude H | OX. | 12.25% RDX |
|----|----------|-----------------------|------------|
| 2. | After f | irst acetone washing | 6.0% RDV |
| 3. | After s | econd acetone washing | 2.0% RD(|
| Ä. | After ti | nird acetone washing | 0.0% PTR |
| | | .1 | el en one |

Proparation of line Particle-size HMX by the Aspirctor Method:

- Dissolve 1100 gm HMX in 4400 cc of dimethyl sulfoxide. Filter the HMX solution.
- Convect a clean aspirator to the water line.
- Convect a clean aspirator to the water line.

 Flace a 55 gallon clean drum under the aspirator.

 Fasten a polyethylene tubing, long enough to reach easily to the bottom of the HMX-dimethyl sulformide container, to the side intake of the aspirator.

 Fasten to the bottom of the aspirator another polyethylene tube long enough to reach to the bottom of the 55 gallon drum.

 Open the water faucet and then place the polyethylene tube in the HMX container.

 Unite milky fine HMX separates out in the drum. Total duration of run is approximately 7 samutam.

- 7 minutes.

 After all the HMX solution is sucked out of the container, the inter is turned off. The material is filtered and water washed.
- 11. If dry HMX is required, the material : n be alcohol and ether washed.

A more efficient method to recover the RDX-HMX mixture:

- 1. Filter the combined hot acetone extracts.
- Pour while agitating the filtered extracts into at least 4 times its volume of water.
 Filter and dry, etc.

beta-HK

Color:

White

Storege:

Mathad

w

Hazard Class (Quant'ty-Distance)

Class 9

Compatibility Group

Group L (dry) Group H (wet)

Emdation

Sone

References: 37

- (:) O. E. Sheffield, E. J. Murray, A. L. Rosen and B. W. Manouse, <u>Properties of HMX</u>, PA Chestial Research Laboratory Report No. 52-TK1-23, 7 April 1952.
 - (b) W. E. Backmann, The Preparation of HMK, OSRD Report No. 1981, 3 November 1943.
- (c) S. Livingston, Characteristics of Explosives HOX and IPEHM, PATR No. 1561, 6 September 1945.
- (d) R. J. Finkelstein and G. Gemow, Theory of the Detonation Process, MAYORD Report No. 90-46, 20 April 1947.
 - (e) O. H. Johnson, HKK as a Military Replosive, MAYORD Report No. 4371, 1 October 1956.
 - (f) Also see the following Picatinny Arsenal Technical Reports on BMX:

1 3 6 7 2 1741 2183 2016 1737 1709 2059

(g) C. Lenchitz, W. Bouch and R. Valicky, Enthalpy Changes, Heat of Fusion and Specific Heat of Basic Explosives, PATR No. 2504, January 1959.

³⁷See footnote 1, page 10.

| Composition: % | | Melecular Weight: | 91 |
|---|---------------------------------------|--------------------------------|---|
| HOCK | 49 | Oxygen Surener: | |
| | • | CO ₂ % | -51 |
| THE | 29 | CO % | -27 |
| Aluminum | 55 | Density: gm/cc Cast | 1.70 |
| • | | Malting Puint: °C | |
| C/H Ratio | · · · · · · · · · · · · · · · · · · · | Freezing Point: *C | |
| Impact Fensitivity, 2 Kg Wt: Bureau of Mires Apparatus, cm | •• | Selline Velat: 'C | |
| Sample Wt 20 mg | | Remotive linies, no | |
| Picatinny Arsenal Apparatus, in. | 17 | ng. | |
| Sample Wt, mg | 25 | - | |
| | | n _s | |
| Friction Pondulum Test: | | Vocema Stability Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Fiber Shoe | Unaffected | 90°C | |
| Riffe Sullet Impact Test: 10 Triols . | 4 | | |
| 3/16" Steel | | 120°C | 0.37 |
| Explosions 30 | 50 | 135°C | |
| Partials and | ** | 150°C | |
| Burned 10 | | 200 Grem Bomb Sand Test: | |
| Unaffected 0 | 50 | Sand, em | 61.3 |
| Explosion Temperature: | °c | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minircum Detonating Charge, gm | |
| 1 | | Mircury Fulminate | |
| 5 Flames erraticall | y 370 | Lead Azide | 0.30 |
| 10 | | Tetryl | **** |
| 35 | | Beflistic Morter, % TNT: | 120 |
| 20 | | Treuxi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | | Plote Dent Test: | |
| 70 LOSS IN 40 FIRS | | Method | |
| 160°C Keet Test | | Condition | |
| % Loss, 1st 48 Hrs | | Confined | |
| % Loss, 1st 40 Hrs | | Density, gm/cc | |
| Explosion in 100 Hrs | | Brisance, % TNT | |
| | | - Derenation Rate: | ~ ~~ |
| Flemmebility Index: | | Confinement | None |
| | | Condition | Cast |
| Hygrescopicity: % | | Charge Diameter, in. | 1.0 |
| | | Density, gm/cc | 1.90 |
| Yeletility: | | | /- |

| Bourtor Sensitivity Test: | | Decomposition Equation: | |
|--|-------------------|---|-------|
| Condition | | Oxygen, atoms/sec | |
| Tetryl, gm | | (Z/səc) | |
| Wax, in, for 50% Detonation | | Heat, kdocolorie/mole (AH, kcs:/mol) | |
| Wax, gm | | Temperature Range, *C | |
| _ | | Phose | |
| Density, gm/cc | | Fridae | |
| Heat of: | 4. | Armer Plate Impact Test: | |
| Combustion, cal/gm | 3 687 | Anna Part Impart Car. | |
| Expla;ion, cal/gm | 1190 | 66 mm Morter Projection: | |
| Gas Volume, cc/gm | 680 | 50% Inert, Velocity, ft/suc | |
| Formation, cal/gm | | Aluminum Fineness | |
| Fusion, cal/gm | | | |
| | | 500-lb General Purpose Bombs: | |
| Specific Heat: col/gm/°C 32 ³ to 74 ⁰ C | 0.01.5 | Plate Thickness, inches | |
| 32 60 74-0 | 0.245 | , | |
| | | <u>j</u> 1 | |
| | | 134 | |
| | | 11/2 | |
| <u> </u> | | 184 | |
| Burning Refe: | | 7 '* | |
| cm/scc | | | |
| | | Somb Drop Test: | |
| Thornol Conductivity: | | | |
| cal/sec/cm/°C | | 17, 2000-th Semi-Armor-Plotting Bemb vs Conc | refe: |
| | | Max Safe Drop, ft | |
| Coefficient of Expansion: Linear, %/*C | | | |
| Linear, 70; C | | 500-lb General Purpose Borsh vs Concrete: | |
| Volume, %/°C | | Height, ft | |
| | | Trials | |
| Herdness, Meh. Seein: | | Unaffected | |
| | | Low Order | |
| Young's Modulus: | | High Order | |
| E', dynes/cm² | | riigh Order | |
| E, lb/inch² | | 1000-lb General Purputs Bomb vs Cenerate: | |
| Density, gm/cc | | Table is denoted to a poor owner to denote of | |
| | 00/- | Height, ft | |
| Compressive Strungth: Ib/inch | 2260 See below | Trials | |
| | '∽e neton | Unaffected | |
| Vapor Prateuro: | | Low Order | |
| °C mm Mercury 2 | | High Order | |
| Compressive Strength: lb/inch | * | _ | |
| Average (10 tests) | 2360 | Ullimate Deformation: % | |
| High | 2530 | Average (10 tests) 2.8 | 81 |
| Low | 1910 | High 3.4 | 22 |

^{*} Test specimen 1/2" x 1/2" cylinder (epproximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwel.

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | | | |
|---|--|----------|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hale Valuine Hole Depth | | | | |
| Total No. of Fragments: For TNT | Colors | Gray | | | |
| For Subject HE 3 inch HE, :442A1 Projectile, Let KC-S: Density, gm/cc Charge Wt, Ib | Principal Uses: HE projectile and bom | b filler | | | |
| Total Mo. of Fragments: For TNT For Subject HE | Method of Looding: | Cast | | | |
| Fragment Velocity: ft/sec | Leading Density: gm/cc | 1.90 | | | |
| At 9 ft At 251/4 ft | Storage: | | | | |
| Density, gm/cc | Method | Lary | | | |
| Black (Relative to THT): | Hazard Class (Quantity-Distance) | Class 9 | | | |
| Air: Pok Pressure Impulse Energy | Compatibility Group Exudation | Group I | | | |
| Air, Conflood: Impulse | Work to Produce Run west ft-1b/inch Average (15 tests) 2. High 3. Low 2. | 77 39 | | | |
| Peak Pressure Impulse Energy | Efflux Viscosit; Saybolt Seconds: | 24.8 | | | |
| Underground: Peak Pressure Impulse Energy | · | | | | |
| च्च च ा प्र 7 | *Test specimen 1/2" x 1/2" cylinder mately 3 gm) pressed at 3 tons (6,0 total load or 30,000 psi with a 2 time of dwell. | 2000 1ь) | | | |

Modulus of Elasticity: *

| | | lb/inch ² |
|---------|---|----------------------|
| Average | - | 89,200 |
| High | ; | 97,400 |
| Low | ; | 76,300 |

* Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Test:

| Critical Pressure | 119,000 psi * |
|-------------------|---------------|
| Density, gm/cc | 1.92 |

* Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Preparation:

Procedure similar to that used for Torpex.

References: 38

- (a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1953. Subject: "Properties of Octols and HTA-3."
- (b) R. Brown and R. Velicky, Heat Capacity of HTM-3, Picatinny Arsenal General Laboratory Report No. 58-H1-509, 5 May 1958.

³⁸See footnote 1, page 10.

Lead Azide

| Composition: | AA-Barrier Mark Aa | | | |
|--|---|--|--|--|
| % | Melecular Weight: (PbN ₆) 291 | | | |
| n 28.8 | Ch; yen Belence: Ch; % -5.5 Ct' % -5.5 | | | |
| Pb 71.2 | Density: gm/cc Crystel 4.80 Dextripated 4.38 | | | |
| | Melting Nint: *C Decomposes | | | |
| C/H Ratio | Freezing Point: "C | | | |
| Bureau of Mines Apparatus, cm 10 Dextrinated | Bailing Paint: *C | | | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 5 Sample Wt, mg 30 28 | Refractive lades. no | | | |
| Friction Pendulus: Test: | Vecum Stability Test: Dextrinated | | | |
| Steel Shoe Explodes | cc/40 Hrs, at | | | |
| Fiber Shoe Explodes | 90°C | | | |
| Rifle Bullet Impact Teet: Trials | - 100°C 1.0 | | | |
| % | 120°C 0.07 | | | |
| Explosions | 153°C | | | |
| Partiols Burry.d | | | | |
| U:infiected | 200 Grum Bomb Send Test: | | | |
| V. W. C. | Black powder fuse 19. | | | |
| Explosion Temperature: 'C | Scasitivity to Initiation: | | | |
| Seconds, 0.1 (no cap used) 390 | Minimum Detonating Charge, gm | | | |
| 1 356 5 Explores 340 | Mercury Fulminate Lead Azide | | | |
| 10 335 | Tetryl | | | |
| 15 335 | | | | |
| 20 335 | Bellistic Morter, % TNT: | | | |
| 75°C International Heat Test: | Trouxi Test, % TNT: (a) 39 | | | |
| % Loss in 48 H-s | Plate Dent Test: | | | |
| 100°C Heet Test: | Condition | | | |
| % Loss, 1st 48 Hrs 0.34 | Confined | | | |
| % Loss, 2nd 48 Hrs 0.05 | Density, gm/cc | | | |
| Explosion in 100 Hrs None | Brisance, % TNT | | | |
| Flommshilty Index: | Detenution Rate: Pure Lead Azide Confinement | | | |
| Mygrescepicity: % Dextrinated Not Dextrinated 0.8 0.03 | Condition Pressed Charge Diameter, in. | | | |
| Veletility: | Density, gm/cc 2.0 3.0 4.0 Rate, meters/second 4070 4630 5180 | | | |

Lead Azide

| Fragmentation Test: | Shaped Charge Effectiveness | Shaped Charge Effectiveness. TNT = 100: | | |
|---|-----------------------------|---|--|--|
| 90 mm HE, AZTI Projectile, Let WC-91: | Glass Cone | uties Cones | | |
| Density, gm/cc | Hole Volume | | | |
| Charge Wt, Ib | Hole Depth | | | |
| | | | | |
| Total No. of Fragments: | Colors | White-buff | | |
| For TNT | 1150 | WILL CO-DUIT | | |
| For Subject HE | Data de al Herre | | | |
| 3 inch itE, M42A1 Projectile, Let KC-5: | and comme | es, priming composition proise blasting caps | | |
| | | | | |
| Density, gm/cc | | | | |
| Charge Wt, Ib | | | | |
| Total No. of Fragments: | Mathad of Lookson | | | |
| For TNT | Method of Looding: | Pressed | | |
| For Subject HE | | | | |
| | Leading Density: gm/cc | psi x 10 ³ | | |
| Fragment Velocity: ft/sec | 3 5 10 | . 15 | | |
| At 9 ft | 2.62 2.71 2.96 | 3.07 | | |
| At 251/4 ft | Sir yes | | | |
| Density, gm/cc | 1 | | | |
| | Method | Wet | | |
| Stact (Relative to TNT): | Hazard Class (Quantity-D | istonce) Class 9 | | |
| Air: | Compatibility Group | Group M (wet | | |
| Peak Pressure | 1 | | | |
| mpulse | Exudation | None | | |
| Energy | | | | |
| | | | | |
| Air, Confined: | Compatibility with Met | als: | | |
| Impulse | Dry lead azide does | not react with or cor- | | |
| | rode steel, iron, nick | el, aluminum, lead, | | |
| Under Water: | zinc, copper, tin or c | | | |
| Peak Pressure | affect coatings of aci | d-proof tlack paint, hellac. Lead azide in | | |
| Impulsa | the presence of moistu | re corroles zinc and | | |
| Energy | | r, it forms the extreme | | |
| Undergreend: | Specific Heat: cal/gm/ | °c | | |
| Pack Pressure | °C | | | |
| Impulse | -50 | 0.110 | | |
| Energy | Ô | 0.110 | | |
| Heat of: | 25 | 0.110 | | |
| Combustion, cal/gm 630 | 50 | 0.110 | | |
| Explosion, cal/gm 367 | Thermal Conductivity: | | | |
| Gas Volume, cc/gm 308 | | | | |
| Formation, cal/gm -346 | cal/sec/cm/°C (Pure |) 1.55 x 10 ⁻⁴ | | |

Load Azide

Compatibility with Natale:

Dry: Steel, iron, nickel, aluminum, lead, zinc, copper, tin, stainless steel, brass and bronze were unaffected by six years' contact with dry lead aside at ambient temperature and 50°C. Momel, chrome-mickel and Incomel were unaffected under the same conditions in two and one-balf years.

Net: Copper and sine are rapidly attacked by moist lead szide, while aluminum is not attacked in 24 hours. Homel, chrome-nickel and Incomel are not attacked by lead szide (25 moisture) after 29 months' exposure at ambient temperature and 50°C, and J-1 magnesium-sluminum alloy is very slightly corroded.

| Sample Tested | Leed Azide | P | Azide lus Water | Lead A | 8 | plus 20% Ethyl Alco- hol (95%) |
|---|---------------|-----------------|------------------------------|--------------------|-------------|--------------------------------------|
| Friction Pendulum Te | et: | | | | | |
| (All IA destrinated) | | | | | | |
| Shoe | Piber | Fiber | Steel | Filber | Steel | Fiber |
| Ho. of Trials Explosions Gracklings Unaffected | 1 0 | 10 0 10 | 12 0 2 10 | 10 0 0 10 | 1 5 1 | 1 1 0 0 |
| Jupect Sensitivity, | 2 Kg kt: | | | | | |
| (All IA dextrinated) | | | | | | |
| PA Apparatus, inc | hes 4 | 9 |) | | 9 | 4 |
| Activation Energy: (| c) | | | | | |
| Koel/mole Induction Period, | seconds | 23.74 0.5-10 | | | | |
| Initiating Efficient | v, Grams Requ | ired to Gi | ve Comple | te Initia | tions of: | |
| | | Dextrinat | ed Azioe | (gm) | | |
| TMT Tetryl ROX PMTM | | | 0.25 0.10 0.05 0.02 | | | |
| Bensitivity to Stati | c Discharge, | Joules (Po | re Lead A | zide) (b) | | 0.0070 |

Leed Azide

Compatibility of Dextrinated Lead Azide with Black Powder: 100°C Vacuum Stability Test, cc/40 hr:

| Sample Wt (gra) | Material | cc |
|-----------------|-------------------------------|------|
| 1.0 | Lead Azide | 0.50 |
| 1.0 | Black Powder | 0.38 |
| 2.0 | 50/50.lend Azide/Black Powder | 1.26 |

Solubility of Pure Lead Azide; gm/100 gm of Water:

| <u>ос</u> | £ |
|-----------|------|
| 20 | 0.05 |

Preparation of Load Azide (Dextrinated): (du Pont procedure)

2 Ha - N = N = N +
$$70 (100_3)_2 \rightarrow Pb(N_3)_2 + 2 NaNO_3$$

Lead nitrate solution: This is prepared by dissolving 164 lbs lead nitrate and 8.25 lb. dextrine in deionized water, the solution allowed to settle, and sodium hydroxide added to bring the solution to a pH of 5.4. The final concentration of the solution is then adjusted to 7.4% lead nitrate, 0.375% dextrine by addition of deionized water.

The lead axios is precipitated at a solution temperature of 160°F, using 60 parts lead nitrate and 50 parts sodium exide solution. The latter is added to the former in 23 minutes, under agitation (no baffles are used in the precipitation vessel), the mixture cooled to room temperaturs in 12 minutes, and allowed to settle 10 minutes. The mather liquor is decented and the remaining slurry washed before packing.

Origin:

First prepared in 1891 by T. Curtius (Ber 24, 3345-6) by adding lead acetate to a solution of sodium or ammonium azide. F. Hyronisus (French Patent 364,792) should be credited with the first attempt in 1907 to use lead azide with some success in the emplosive industry. Its commercial manufacture started in Burye before World War II and in the United States since 1931 as military or commercial grade "dextrinated" lead azide.

Destruction by Chemical Decomposition:

Lead axide can be decomposed by

- (1) mixing with at least five times its weight of a 10% solution of sodium hydroxide and allowing the mixture to stand for 16 hours. Decant the supermatant solution of sodium azide and drain into the soil.
- (2) dissolving in a 10% solution of ammonium accrete and adding a 10% solution of sodium or potassium bichromate until no more lead chromate is precipitated.
- (3) wetting with 500 times its weight of water, slowly adding 12 times its weight of 25% sodium mitrite, stirring, and then adding 14 times its weight of 36% nitric or glacial acetic acid. A red color produced by the addition of ferric chloride solution indicates Lead Azide is still present.

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Lead Azide

(4) dissolving in 50 times its weight of 15% ceric ammonium nitrate. The azide is decomposed with the evolution of nitrogen.

References: 39

- (a) Ph. Haoum, Z ges Schiess Sprengstoffe, 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kuzler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Burcau of Mines, RI 3852, 1946.
- (c) C. Lenchitz, Ice Calorimeter Determination of Enthalry and Specific Heat of Eleven Organometallic Compounds, PATR 2224, November 1955.
 - (d) Also see the following Picatinuy Assemal Technical Reports on Lead Azide:

| <u>o</u> | 1 | 2 | 3 | 4 | 2 | <u>6</u> | I | <u>8</u> | 2 |
|----------------------------------|----------------------------|--|-------------------------------------|-----------------------------|-------------------------------------|---|--|---|--|
| 550 580 600 760 1450 | 561 861 1451 1651 | 832 852 882 932 1132 1152 1352 1372 | 393 1393 1493 2093 2133 | 2164 2164 2164 234 | 255 525 1 3 25 1485 | 326 856 866 1316 1486 1556 | 567 637 657 707 1737 2227 | 628 708 748 788 836 1388 1528 1638 2198 | 609 719 749 769 849 999 2179 |

³⁹See footnote 1, page 10.

| Composition: | Melacular Weight: (PbC6H2N2O6) 405 |
|--|--|
| C 17.8 H 0.5 N 6.9 | Oxygen Belence: CO ₂ % -32 CO % - 8 |
| 0 23.7 Pb 51.1 | Density: gm/cc Crystal 3.2 |
| <u>\</u> | Melting Point: 'C |
| C/H Ratio 0.549 | Freezing Point: *C |
| Burgou of Mines Apparatus, cm 1 kg at 30 | Boiling Point: 'C |
| Bureau of Mines Apparatus, cm 1 kg wt 30 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20 | Refractive Index, no |
| Friction Pendulum Test: Steel Shoe Fiber Shoe | Vecuum Stebility Test: cc/40 Hrs, at 90°C 100°C |
| Rifle Bullet Impact Test: Trials 96 Explosions Partials | 120°C (73 minutes) Explodes 135°C 150°C |
| Burned Unoffected | 200 Grem Bemb Send Test: Sand am Black powder fuse 20 |
| Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Explodes 265 10 15 | Sassitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl |
| 20 | Bellistic Morter, % TNT: |
| | Trouzi Test, % TNT: |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Alerino |
| 100°C Heart Test: | Condition Confined |
| % Loss, 1st 48 Hrs 0.20 | Density, grr/cc |
| % Loss, 2nd 48 Hrs 3.02 Explosion in 100 Hrs None | Brisance, % TNT |
| Flammability Index: | Detenation Rate: Confinement |
| Hygrescapicity: % 30°C, 90% RH 0.73 | Condition Charge Diameter, in. |
| Volatility: | Density, gm/cc Rate, meters/second |

AMCP 706-177

Lead 2,4-Dinitroresorcinate (LDNR)

| r yellow detonators Pressed Wet Class 9 |
|---|
| Pressed Wet Class 9 |
| Pressed Wet Class 9 |
| Wet Class 9 |
| Class 9 |
| Class 9 |
| Class 9 |
| • |
| None |
| |
| LDNR does not |
| 270 |
| · |
| |

Preparation:

To a solution of 5 grams of purified dinitroresorcin and 2.65 grams of anhydrous sodium to in 500 ec of boiling water is added slowly a solution of 10 grams of lead nitrate assolved in 60 ec of boiling water. The reaction mixture is constantly stirred during the addition of the lead salt and for about an hour afterward while the solution is allowed to cook to room temperature. The precipitate is filtered and washed thoroughly first with water and then with alcohol as either. It is dried in a steam oven.

Origin:

2,4-dinitroresorein was described in the 1881 edition of Beilstein (Beil VII, 885). The same conjound was described in more detail by Weselsky, Benedikt and Ribl in 1882 (M II, 323). The land salt of 2,4-dinitroresoreinol appears to have been prepared between World War I and World War II by treating resoreinol with nitrous acid and oxidizing the resulting dinitrosoresoreinol to dinitroresoreinol. Lead nitrate solution was then added to a solution of the 2,4-dinitroresoreinol to which sodium carbonate had been added to form the soluble sodium salt (J. D. Fopper, PATR No. 480, March 1954). The LYBR exists in two forms differing in physical characteristics but possessing similar explosive properties. These forms are red and orange in color (K. S. Warren, PATR 1448, September 1944).

sfer 40

(a) See the following Picatinny Arsenal Technical Reports on Lead 2,4-Dinitroresorcinate:

| <u>o</u> | 3 | <u>4</u> | <u>8</u> | 2 |
|------------|-----|----------|--------------|-------------|
| 480 580 | 453 | 1004 | 1328 1448 | 859 1079 |

⁴⁰See footnote 1, page 10.

Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

| Composition: | Meloculer Weight: (Pb2C6H4N2O8) 646 |
|--|---|
| % 0-P5-OH C 11.2 H 0.6 N 4.3 02N | Oxygen Science: -20 CO₂ % -5 |
| 0 19.8 Pb 64.1 | Density: gm/cc |
| NO ² | Melting Point: °C 213 |
| C/H Ratio 0.177 | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 1 kg vt 60 | Bailing Point: *C |
| Sample Wt 20 mg Picaninny Arsenal Apparatus, in. Sample Wt, mg 20 | Refrective Index, no. no. no. |
| Friction Pondulum Test: Steel Shoe Fiber Shoe | Vector Stability Test: cc/40 Hrs, at 90°C |
| Riffe Bullet Impact Test: Trials ### Explosions Partials | 100°C 120°C 135°C 150°C |
| Burned Unaffected | 200 Green Bomb Sond Test: SMGsP Bowder fuse 15 |
| Explosion Temperature: *C Seconds, 0.1 (no cop used) 1 5 Explodes 295 10 15 20 | Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl Belliatic Morter, % 'ENT: |
| | Trouzi Test, % TNT: |
| 75°C Internetional Heat Test: % Loss in 48 Hrs | Plate Dent Test: Methori |
| 100°C Heat Test: | Condition Confined |
| % Loss, 1st 48 Hrs 0.4 % Loss, 2nd 48 Hrs 0.0 | Density, gm/cc |
| Explosion in 100 Hrs None | Brisance, % TNT |
| Flommability Index: | Detenation Rate: Confinement |
| Hygrescepicity: % | Condition Charge Diameter, in |
| Voletility: | Density, gm/cc Rate, meters/sucond |

Lead 4,6-Dinitrorenorcinol Basic (LDNR Basic)

AMCP 706-177

| regressiation Test: | Shaped Charge Effectiveness, TNT = 100: |
|--|---|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones |
| Density, gm/cc | Hole Volume |
| Charge Wt, Ib | Hole Depth |
| Total No. of Fragments: | Color: Red or yellow |
| For TNT | |
| For Subject HE | Principal Uses: Electric detonators |
| 3 inch HE, M42A1 Projectile, Let KC-5: | |
| Density, gm/cc | |
| Charge Wt, Ib | |
| Total No. of Fragments: | Method of Looding: Pressed |
| For TNT | Treaser. |
| For Subject HE | |
| | Leading Dentity: gm/cc |
| regment Velocity: ft/sec | |
| At 9 ft | |
| At 251/4 ft | Storege: |
| Density, gm/cc | Method Wet |
| | THE |
| last (Relative to TNT): | Hazard Class (Quantity-Distance) Class 9 |
| Airs | Compatibility Group |
| Peak Pressure | |
| Impulse | Exudation Kone |
| Energy | |
| <u> </u> | Tuthtaking Detterance O.b. on 1700 Dank |
| Air, Confined: | Initiating Efficiency: 0.4 gm LDNR Basic does not initiate tetryl pressed at 3000 |
| Impulse | pai. |
| Under Water: | |
| Peak Pressure | |
| Impulse | |
| Energy | |
| Underground: | |
| Peak Pressure | 1 |
| Impulse | |
| Energy | |
| | į |
| | |
| | |
| | I |

AMCP 706-177

Lead 4,6-Dinitroresorcinol Basic (LDNR Basic)

Preparation:

- (a) One hundred grams of pure resorcin is fused in a porcelain casserole and immediately poured on a glass plate. After cooling, the cake is ground in a mortar to pass a U. S. Standard No. 6 mesh screen. Four hundred grams of 98 percent nitric acid in a one pint capacity Dewar jar is stirred mechanically while carbon dioxide snow is added in small pieces. When the temperature falls to -20°C, 40 grams of the granulated resorcin is added in small quantities. Simultaneous addition of solid carbon dioxide as required prevents a rise of temperature of more than 5 degrees throughout the entire experiment. Five minutes after the last portion of resorcin is introduced, the mixture is further cooled to minus 50°C, and finally drowned with vigorous stirring in five times its volume of cracked ice, in water. This mixture is allowed to stand for one hour and the product then filtered, washed, and partially dried, weight \$3.6 grams. The crude \$4.6-DRR is purified by first dissolving the product in an aqueous 5 percent sodium hydroxide solution (17.4 grams of sodium hydroxide in 3%0 cc of water). The resulting solution is then neutralized by gradually adding it to a boiling solution of 21.4 grams of 96 percent sulphuric acid in 150 cc of water. The resulting precipitate of \$4.6-DRR is filtered hot on a suction filter and air-dried. Yield, 27.5 grams (37.8 percent of the theoretical).
- (b) Five hundredths (0.05) mole (18.96 grams) of lead acetate is dissolved in 67 cc of warm water, into which is gradually stirred 0.10 mole (4.0 grams) of sodium hydroxide dissolved in 67 cc of water. Stirring is continued for five minutes. After settling, the white lead hydroxide is washed by decentation three times with 100 cc portions of distilled water, and used immediately for the next operation.
- (c) A 0.0278 mole (5.56 grams) quantity of the 4,6-IMR prepared under (a) above, is dispersed in 270 cc of water by vigorously beating with a motor stirrer. After heating this dispersion to 90°C, the 0.05 mole of lead hydroxide prepared above in slurry form is introduced in small portions. Agitation is continued for three hours at 90°C. The basic lead 4,6-IMR is washed duce by decantation, and again on the filter with alcohol. After drying overnight in a desiccator charged with calcium chloride, the product weighs 15.6 grams.

Origin:

Both the 2,4- and 4,6-dinitroresorcin were described in some detail by Weselsky, Benedikt and Hübl in 1882 (M II, 323). Typke prepared the 4,6-dinitroresorcin in 1883 by hydrolyzing the nitration product of resorcin discetate (Ber 16, 551). A sore direct and economical method of preparation suitable for production scale manufacture was developed during World War II by the British (Ministry of Supply Pouch Item W-154-21s, "Manufacture of 4,6-Dinitroresorcin and Lead 4,6-Dinitroresorcinate"). This procedure consisted of preparing 4,6-dinitroresorcinol by direct nitration of granulated resorcin and allowing the product in slurry to react with an excess of lead hydroxide at 90°C. This basic salt can be prepared in two forms: (1) a micro-crystalline, yellow, low-density form and (2) a denser, brick-red form. Both products have the same chemical composition and the same sensitivity to impact (PATE 1448, September 1944).

Lead Styphnate

| Composition: | Molecular Weight: (PbC6H3N3O9) 468 | |
|---|---|---|
| C 15.4 H 0.6 N 9.0 | Oxygen Belance: CO ₂ % -19 CO % 2 | |
| 0 30.8 Pb 44.2 | Density: gm/cc Crystal 3.02 | |
| NO ₂ | Molting Point: °C Explodes 260-310 | |
| C/H Ratio 0.320 - 2 | Freezing Point: *C | |
| Impact Sociality, 2 Kg We: Bureau of Mines Apparatus, cm | Boiling Point: °C | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (8 oz wt) Sample Wt, mg | Refrective Index, no. no. no. no. | |
| Friction Pendulum Test: | Vacuum Stability Tert: | _ |
| Steel Shoe Detonates Fiber Shoe Detonates | cc/40 Hrs, at 90°C | |
| | 100°C 0.4 | |
| Riffie Bullet Impact Test: Triols | 120°C 0.3 | |
| % Explosions | 135°C | |
| Partials | 150°C | |
| Burned | 200 Grem Bemb Sand Test: | |
| Unaffected | Sond om 24 Black powder fuse 11.1 | |
| Explanion Temperature: 'C | | |
| Explosion Temperature: 'C Seconds, 0.1 (no cap used) | Sensitivity to Initiation: Minimum Detonating Charge, gm | |
| 1 | Mercury Fulminate Trace# | |
| 5 Explodes 282 | Lead Azide Trace | |
| 10 276 | * <. Of gm, alternative | |
| 15 272 | | |
| 2C 267 | Ballietic Morter, % TNT: | |
| TRIC International Mana Tout. | Treuxi Test, % TNT: (a) 40 | |
| 75°C International Heat Tent: % Loss in 48 Hrs | Plate Dent Test: Method | |
| 100°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs 0.38 | Confined | |
| % Loss, 2nd 48 Hrs 0.73 | Density, gm/cs | |
| Explosion in 100 Hrs None | Brisance, % TNT | |
| Flommability Index: | Detenction Rate: Confinement | |
| Hygruscapicity: % 25°C, 100% RH 0.05 30°C, 90% RH 0.02 | Condition Charge Diumeter | |
| Volutility: | Density, gm/cc 2.9 | |
| | Rate, meters/second 5200 | |

Lead Styphnate

| Fregmentation Test: | Sheped Charge Effectiveness, TNT := | 1 00 : |
|---|--|-------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel | Cones |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | Color: Orange-reddish b | rown |
| For TNT | | |
| For Subject HE | Principal Uses: Igniting charge, | and ingrediert |
| 3 inch HE, M42A1 Projectile, Let KC-5: | of priming compo | |
| Density, gm/cc | 1 } | |
| Charge Wt, Ib | | |
| Total No. of Fragments: | Mished of Loading: | Pressed |
| For TNT | 1 | |
| For Subject HE | Leeding Density: grn/cc | |
| Frequent Velocity: ft/sec | and the same of th | |
| At 9 ft At 251/2 ft | Storege: | |
| Density, gm/cc | Method | Wet |
| Signt (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 |
| Air: | Compatibility Group | Group M (wet) |
| Peak Pressure | | |
| Impulse | Exudation | None |
| Energy | | |
| Air, Confined: | Activation Energy: | |
| Impulse | kcal/mol | 75 ·3 9 |
| Under Water: | Induction Period, sec | 0.5-10 |
| Pook Pressure | 2 | (c) |
| Impulsy | Specific Heat: cal/cm/°C | (6) |
| Energy | <u>°c</u> | |
| Underground: | -50 | 0.141 0.158 |
| Peak Pressure | 0 25 | 0.164 |
| Impulse | 50 | 9.167 |
| Energy | | |
| Hest of: | | |
| Combustion, cal/gm 1251 Explosion, cal/gm 457 | | |
| Ges Volume, cc/gm 368 Formation, cal/gm -92 | | |
| Formation, cal/gm -92 | | |

STATE OF THE PROPERTY OF THE PARTY OF THE PA

Preparation:

Dissolve 14.4 gm lead nitrate and 1 cc of 36% acetic axid in 320 cc distilled water. Dissolve 4 gm 2,4,6-trinitroresorcinol and 1.73 gm sodium componate in 80 cc distilled water. Add the 1.ed acetate solution to the trinitroresorcinol solution, under agitation, keeping the temperature at 70°-75°C and continue stirring for 3 hours at this temperature. Cool to 20°C in 5 hours. Evaporate the solution to 1/3 its volume, cool, filter and wash the product well with water (to neutrality).

| Sensitivity to Static Discharge, joules: (b) | 0.0009 |
|---|----------------------|
| Loss in Weight at 105°C: \$ | |
| 3 hours 6 hours 9 hours | 0.02 0.23 0.23 |
| Effect of Storage for 2 Months at 30°C, on: | |
| Explosion Temperature Test Value Sand Test Value | Nil Nil |

Sensitivity to Initiation Solubility, gm/100 gm (\$) in:

Glycol Diacetate

°c ½

20-25 0.1

Origin:

First described in 1914 by von Hurtz and found to be a relatively poor initiator by Wallbaum in comparison to other primary explosives. (Z ges Schiess Sprengstoffw 34, 126, 161, 197 (1939)). Moisak showed that lead styphnate could be used as an insulating (cover) material for lead azide providing protection from mechanical and chemical influences and, at the same time, increasing the detonating ability of the total charge (Transactions of Butlerov Inst Chem Tech Kasen (Russia) 2, 81-5 (1935).

Lead Styphnate

Destruction by Chemical Decomposition:

Lead styphnate is decomposed by dissolving it in at least 40 times its weight of 20% socium hydroxide or 100 times its weight of 20% ammonium acetate and adding a solution of sodium dichromate, equal to half the weight of styphnate and 10 parts of water.

References: 41

- (a) Suport AC-9,56/Org Ex 74.
- (b) F. W. Brown, D. H. Kurler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (c) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven.
 Organometallic Compounds, PATR No. 2224, November 1955.
 - (d) Also see the following Picatinny Arsenal Technical Reports on Lead Styphnate:

| <u>o</u> . | <u>1</u> | 2 | <u>3</u> | <u> 4</u> | <u>6</u> | I | <u>8</u> | 2 |
|--------------|----------|--------------|---------------------|-----------|----------|---------------------|----------|------|
| 1450 2220 | 11 | 1352 2032 | 453 20 93 | 2164 | 1316 | 407 1737 2077 | 318 | 2179 |

⁴¹See footnote 1, page 10,

Mannitol Hamanitrate (Nitromannite)

| Composition: CH2ONO2 | Molecular Weight (C6H8N6O18) 452 |
|---|---|
| O_NOCH | Oxygen Belance: |
| O MOGR | CO ₃ % 7.1 CO % 28 3 |
| NOONO . | Density: gm/cc 1.73 |
| ж 18.6 номо ₂ | Melhing Paint: °C 112-113 |
| 0 63.8 CH ₂ ONO ₂ | |
| C/H Ratio 0.133 | Freezing Point: *C |
| Impect Sonsitivity, 2 Kg Wr: Bureou of Mines Apparatus, cm 11 | Builing Point: °C Decomposes 150 |
| Sample 1/1 20 mg | Refrective Index, no. |
| Picotinny Arsenot Apparatus, in. 4 Somole Wt. mc 31 | n 💂 |
| Sample Wt; mg | n _{so} |
| Friction Pendulum Tost: | Vecuum Stebility Test: |
| Steel Shoe Detonates | cc/40 Hrs, at |
| Fiber Shos Unaffected | 90°C |
| Riffe Bullet Impact Test: Tricls | 100°C |
| % | 120°C |
| Explosions | 135°C |
| Partials | 130°C |
| Burned | 200 Gram Famb Sand Test: |
| Unoffected | Sand, ;m 68.5 |
| Explacion Temperature: "C | Sansitivity to Initiation: |
| Seconds, 0.1 (no cop used) 160-170 (a) | Minimum Detanating Charge, gm |
| 1 232 (b) 5 175 (c) | Mercury Fulminate |
| 5 175 (c) | Lead Azide 0.06 |
| 15 | Tetryl |
| 20 | Ballistic Morter, % THT: |
| | Trous Test, % TNT: (c) 172 |
| 75°C International Heat Test: % Loss in 48 Hrs 0-4 | Plate Deat Test: Method |
| 10010 Mark Tank | Condition |
| 100 °C Heat Test: % Loss, 1st 48 Hrs | Confined |
| % Loss, 2nd 48 Hrs | Density, gm/cc |
| Explosion in 100 Hrs (Frothed) 48 hours | Brisance, % TNT |
| Explosion in too instance to hours | — Detenation Rate: (d) |
| Flammab#Ay Index: | Confinement Yes |
| | Condition Pressed |
| | Ct Di |
| Hygrescopicity: % 30°C, 99% III 0.3.7 | Charge Diameter, in. 0-5 |
| Mygreccepicity: % 30°C, 90% RH 0.1.7 Volctility: | Density, gm/cc 1.73 Rate_meters/second 8250 |

Mannitol Hexanitrate (Nitromannite)

| Fragmentation Test: | Shapird Charge Effectiveness, TNT = 100: | , |
|--|---|------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Flass Cones Steel Cones | • |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | | |
| For TNT | Color: | |
| For Subject HE | | · . |
| | Principal Uses: Secondary charge in det | onators |
| 3 inch HS, M42A1 Projectile, Let KC-5: | (ref i), and in blasting caps des be initiated by a fuse (ref j) | igned t |
| Density, gm/cc | , | |
| Charge Wt, Ib | | • |
| Total No. of Freyments: | Method of Leading: Pres | |
| For TNT | Method of Leeding: Pres | sed |
| For Subject HE | | |
| | Leeding Density: gm/cc | . * |
| regment Velocity: ft/sec | | |
| At 9 ft At 25½ ft | *a | |
| | Sterege: | |
| Density, gm/cc | Method Dry | |
| lest (Relative to TNT): | Hozard Class (Quantity-Distance) Class | 9 |
| Airz | Compatibility Group | |
| Peak Pressure | Containomy Group | |
| Impulse | Exudation None | |
| Energy | none | |
| Creatgy | | |
| Air, Confined: | 65.5°(Kl Test: | |
| Impulse | Minutes 6 | |
| 10-A M | Manages 0 | |
| Under Weter: Peak Pressure | Heat of: (e, f, g) | |
| Impulse | Combustion, cal/gm 1515 1525 | - |
| Energy | Explosio, cal/gm 1390 1454 1468 | 1520 66 |
| Underground: | 1, 5 55 5 | , |
| Peak Pressure | · | |
| Impulse | | |
| Energy | | |
| | .] | |
| | | |
| | | |
| | | |

Mannitol Hexanitrate (Nitromannite)

Solubility:

- a. Insoluble in water.
- b. Slightly soluble in cold alcohol (2.9 gm at 13°C).
- c. Slightly soluble in ether (4 gm at 9°C).
- d. Very soluble in hot alcohol.

Preparation: (Laboratory Method) (k)

- Cool to below 0°C, 50 gm of 98%-100% nitric acid placed in a 300 milliliter Erlenmeyer Pyrex flask provided with a thermometer and immersed in an ice-salt mixture.
- b. Introduce in small portions, 10 gm of d-mannitol, while swirling the clask to break up any lumps of mannite which might form. Keep the temperature below 0°C.
- c. After solution is complete, add 100 gm of concentrated sulfuric acid from a dropping funnel, swirling the flask in an ice-salt mixture to keep the temperature below 0°C.
- d. Filter the resulting porridge-like slurry through a filter paper previously hardened by treatment with mixed acid.
- e. Rinse the precipitate directly on the filter with water followed by dilute aqueous sodium carbonate and finally with water. (The resulting crude mannitol hexanitrate gives 15.2% H as altermined by the nitrometer.)
- Dissolve the crude mannitol hexanitrate in boiling alcohol and filter through a waterheated funnel.
- Bring the filtrate to boiling and gradually add hot water until the appearance of the first turbidity.
- h. Cool in an ice-salt bath, separate and dry the crystals. (Yield should be about 23 gm of material, melting at 1120-1130C and having 18.58% N, the nitrogen being determined by the nitrometer. Theoretical yield would be 24.8 gm.)

Mannitol hexanitrate was discovered in 1847 by Ascanio Sobrero who recommended it as a substitute for mercury fulminate in percussion caps (Comp rend. 1847, 121). It is the hexanitric ester of d-ramnitol which is widely distributed in nature, particularly in the plant Frankous ornus. N. Sokoloff, a Russian chemist, investigated the explosive properties of his and recommended in 1878 a method of preparation. Mannitol hexanitrate was thoroughly studied by Merthelot, Sarran and Vicille. Example, Menard, Strecker, Tichanowich (Ph. Naoum, Nitroglycerin and Nitroglycerin Emplosives, Baltimore, 1928, pp. 156, 247-250), and particularly by J. H. Wigner (Ber 36, 796 (1903)). More recent data have been reviewed by Guastalla and Racciu ("Modern Emplosives," Industria Chimica 8, 1093-1102 (1933)).

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(a) G. C. Hale, Abstract of Available Information on the Preparation and Explosive Properties of Hexanitromannite, PA Special Report No. 238, 30 July 1925.

⁴²See footnote 1, page 1C.

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Mannitol Hexanitrate (Nitromannite)

- (b) C. A. Taylor and W. H. Rinkenbach, "Sensitiveness of Detoneting Compounds to Frictional Impact, and Heat," J. Frank Inst 204, 369-76 (1927).
 - (c) Ph. Haoum, Z ges Schiess Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
 - (d) H. Kast, Z angew Chem, 36, 74 (1923).
 - (e) A. Schmidt, Z ges Schiess Sprengstoffw 29, 262, (1934).

 Isodolt and Börnstein, E III, p. 2914.
- (?) A. Marshall, Explosives, Their Manufacture, Properties, Tests, and History, Vol III, London (1932) p. 39. Ph. Macum, Mitroglycerin and Mitroglycerin Explosives, Baltimore, (1926), pp. 156, 247-250.
- (g) A. Schmidt, Z ges Schiess Sprengstoffw 29, 262 (1934) G. Fleury, L. Brissend and P. Ihoste, "Structure and Stability of Mitric Esters," Comp rend 224, 1016-18 (1947). W. R. Tomlinson, Jr., Fundamental Properties of High Explosives. Thermodynamic Relations for Use in the Estimation of Explosive Properties, PATR No. 1651, 22 April 1947.
 - (h) Sarran and Vielle, Mem poudr 2, 161 (1884-1889).
 - (i) L. von Hurtz, U. S. Patent 1,878,652 (20 September 1932).
 - (j) L. A. Burrows, U. S. Patent 2,427,899 (23 September 1947).
- (k) B. T. Fedoroff, Bandbook of Explosive and Related Items, Picatinny Arsensl (unpublished).
- (i) O. E. Sheffield, Literature Survey on Munnitol Hexanitrate, PA Chemical Research Laboratory Report No. 52-TMI-16, 23 January 1952.
 - (m) Also see the following Picatinny Arsenal Technical Reports on Manmitol Hemanitrate:

2 ½ 2 6 1352 24 85 6

Mercury Fulminate

| Composition: | Addanda Malaha (n.a.n.a.) |
|--|---|
| % | Molecular Weight: (HgC ₂ N ₂ O ₂) 285 |
| $c = 8.4 \qquad o-n-c$ | Oxygen Belence: |
| | CO ₂ % -17 .5.5 |
| | Density: gm/cc Crystal 4.43 |
| 0 11.2 0 -N - C | AA-Di Di A |
| Hg 70.6 C/H Ratio | |
| | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: Bureou of Mines Apparatus, cm 5; (1 kg Vt) 35 | Bolfag Point: *C |
| Sample Wt 20 mg | Refrective Index, no |
| Picatinny Arsenal Apparatus, in. 2; (1 1b wt) 4 Sample Wt, rng 30 | I _D |
| 55 | n <u>e</u> |
| Friction Fendulum Test: | |
| Sheel Shoe Explodes | Vecuum Stability Test: cc/40 Hrs, at |
| Fiber Shoe Explodes | 90°C |
| 0.00 | 100°C Explodes |
| Rifle Bullet Impact Test: Trials | 120°C |
| % Explosions | 135°C |
| Portiols | 150°C |
| Burned | 200 Grem Bemb Sand Test: |
| Unaffected | Sand. am |
| Explosion Yemperature: *C | |
| Seconds, 0.1 (no cop used) 263 | Sensitivity to Initiation: Minimum Detonating Charge, gm |
| 1 239 | Mercury Fulminate |
| Explodes 210 | Lead Azide |
| 199 | Tetryl |
| 15 194 | |
| 20 190 | Ballietic Mertar, % TNT: |
| 75°C International Heat Test: | Trouxi Test, % TNT: (a) 51 |
| % Loss in 48 Hrs 0.18 | Plate Dent Test: |
| | Method |
| 100°C Heet Test: Exploded in 16 hours | Condition |
| % Loss, 1st 48 Hrs | Confined |
| % Loss, 2nd 48 Hrs | Density, gm/cc |
| Explosion in 100 Hrs | Brisonce, % TNT |
| Flammebility Index: | Detenation Rate: |
| resume surprise and the | Confinement |
| Hygrescepicity: % 30°C, 90% RH 0.02 | Condition Pressed |
| | Charge Diameter, in. |
| Veletility: | Density, gm/cc 2.0 3.0 4.0 |
| - | Rate, meters/second 3500 4250 5000 |

Mercury Fulminate

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 100: |
|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones |
| Density, gm/cc | Hole Volume |
| Charge Wt, Ib | Hole Depth |
| Total No. of Fragments: | Celer: White to gray |
| For TNT | 111111111111111111111111111111111111111 |
| For Subject HE | Principal Uses: Detonators and ingredient of |
| 3 inch HE, M42A1 Projectile, Let KC-5: | priming compositions |
| Density, gm/cc | |
| Charge Wt, Ib | |
| Total No. of Fragments: | Method of Londing: psi x 10 ³ |
| For TNT | 3 5 10 12 15 20 |
| For Subject HE | 3-00 3.20 3.60 3.70 3.82 4.00 |
| | Leading Dansity: gm/cc |
| Fregment Velocity: ft/sec | |
| At 9 ft | |
| At 251/2 ft | Storage: |
| Density, gm/cc | Method Wet |
| | |
| Bleet (Relative to TNT): | Hazard Class (Quantity-Distance) Class 9 |
| Air: | Compatibility Group Group M (wet |
| Peak Pressure | |
| Impulse | Exudation None |
| Emergy | |
| Air, Confined: | Stab Sensitivity: |
| Impulse | Density Firing Point (inch-ounces) |
| • | gm/cc 04 504 1004 |
| Under Water: | 3.91 3.2 4.3 5.5 4.26 1.6 2.6 5.5 |
| Peak Pressure | 1.32 1.6 2.6 4.0 |
| Impulse | 4.50 1.6 2.5 4.0 |
| Energy | Activation Energy: |
| | kcal/mei 29.81 |
| Undergreund: Peak Pressure | Induction Period, sec 0.5-10 |
| Impulse | Heat of: |
| | Combustion, cal/gm 938 Explosion, cal/gm 427 |
| Energy | Gas Volume, cc/gm 243 |
| - | Formation, cal/gm -226 |
| | Formation, cal/gm -226 |
| | Specific Heat: cal/gm/°C 1.1 |
| | , |

Mercury Fulminate

Initiating Efficiency; Grams Required to Give Complete Initiation of:

Fulminate, gm

| TNT | 0.25 |
|--------|------|
| Tetryl | 0.20 |
| RDX | 0.19 |
| PETE | 0.17 |

Compatibility with Metals:

Dry: Reacts rapidly with aluminum and magnesium. Reacts slowly with copper, zinc, brass and bronze. Iron and steel are not affected.

Wet: Reacts immediately with aluminum and magnesium. Reacts rapidly with copper, zinc, brass and bronze. Iron and steel are not affected.

Sensitivity to Static Discharge, Joules: (b)

0.025

The Effect of Storage at 50°C (Dry) on the Purity of Mercury Fulminate

| 1 | ecrystall: | ized Lots | Uncrystallized Lots | | |
|-------------------------|--|--|--|--|--|
| 272 | 980 | 981 | <u>982</u> | 505.6-7/31 | 505.3-5/11 |
| 99-75 | 99-77 | 99-79 | 99.79 | 98.86 | 98.7 |
| ∳\$1 3 6 | 99.45 | 99.54 | 99.47 | 95-95 | 98.7 97.4 |
| | | | | 94.95 | 94.9 |
| 98.74 98.26 98.22 | 99.56 | 97.49 | 99.06 98.79 | 90.65 | |
| 97.52 97.00 | 99.30 98.66 | 99.30 99.01 | 98.19 97.75 96.69 | 83.76 | |
| 94.81 | 98.58 | 98.45 | 95.90 | 79.99 74.52 63.80 | |
| | 99.75 99.75 98.74 98.26 98.22 97.52 97.50 95.70 | 99.75 99.77 99.75 99.77 99.36 99.45 98.74 99.56 98.26 98.26 98.22 97.52 99.30 97.00 95.70 98.66 | 99.75 99.77 99.79 95.36 99.45 99.54 98.74 99.56 97.49 98.26 98.22 97.52 99.30 99.30 97.00 99.01 95.70 98.66 | 99.75 99.77 99.79 99.79 99.75 99.45 99.54 99.47 98.74 99.56 97.49 99.06 98.26 98.79 98.22 97.52 99.30 99.30 98.19 97.00 99.01 97.75 95.70 98.66 | 979 980 981 982 505.6-7/31 99.75 99.77 99.79 98.86 95.36 99.45 99.54 99.47 95.95 94.95 94.95 94.95 94.95 98.74 99.56 97.49 99.06 90.65 98.26 98.79 98.79 98.79 96.22 97.52 99.30 98.19 83.76 97.00 99.01 97.75 95.70 96.69 94.81 98.58 98.45 97.90 79.99 74.52 |

Chemistry:

Mercuric fulminate readily decomposes in the presence of aqueous solutions, chlorides, carbonate and many other materials. Due to the presence of small amounts of mercury, formed by exposure to light or elevated temperatures, it readily forms amalgams with copper, brass and bronze, thus components containing these metals must be protectively coated if used with fulminate.

Solubility, Grams of Mercury Fulminate in 100 Grams of Water (%):

| <u>°c</u> | 至 |
|-----------|------|
| 12 | 0.07 |
| 49 | 0.18 |

Preparation:

(Chemistry of Powder and Explosives, Davis)

$$CH_3 - CH_2 - OH \longrightarrow CH_3 - CHO \longrightarrow CH_2 - CHO \rightleftharpoons CH - CHO$$

$$H \longrightarrow H_0 OH$$

$$N - OH$$

Five gm mercury is dissolved in 25 cc of nitric acid (sp gr 1.42) without agitation, and this solution poured into 50 cc of 90% ethyl alcohol, resulting in a vigorous reaction, attended by evolution of white fures and subsequent appearance of fulminate crystals. Red fuses then appear as precipitation of the product accelerates, and then white fuses again are evolved as the reaction moderates. After about 20 minutes the reaction is over; water is added, and the crystals are repeatedly washed, by decentation, with veter to remove all acidity. The product is purified, rendered white, by solution in strong ammonium hydroxide, followed by reprecipitation with 30% acetic acid.

Origin:

Mercury fulminate was first prepared by John K. von Lowenstern (1630-1703) and in 1800 its preparation and properties were first described in detail by Edward Howard in a paper presented to the Royal Society of London (Phil Trans, 204 (1800). It was 1867 before the compound was used as an initiating agent, when Alfred Nobel invented the blasting cap and used mercury fulminate to detonate nitroglycerin (British Patent 1345 (1867)).

Destruction by Chemical Decomposition:

Mercury fulminate is decomposed by adding it, while stirring, to at least 10 times its weight of 20% sodium Chiosulfate. Some poisonous cyanogen gas may be evolved.

References: 43

- (a) Fh. Macum Z ges Schiess-Sprengstoffw (Munich), pp. 181, 229, 267 (27 June 1932).
- (b) F. W. Brown, D. H. Kusler, and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.

⁴³See footnote 1, page 10.

ercury Fulminate

AMCP 706-177

| (c) | Also see | the | following | Picatinny | Arsenal | Techni | cal Re | orts on | Mercury | Fulminate: |
|-----|---|---------------------------|--|--|---|--|--|---|---------------------------------------|---|
| | <u>o</u> | 1 | 2 | <u>3</u> | 4 | 2 | <u>6</u> | I | <u>8</u> | 2 |
| | 250 480 510 550 610 660 760 1220 1450 | 301 381 561 1651 | 132 452 582 582 782 882 932 11352 1372 1722 2032 | 23 203 393 433 833 1183 1393 2093 | 144 294 534 624 694 784 874 1104 | 65 105 255 285 365 415 425 1325 1365 | 266 366 556 566 865 986 1316 1486 1556 2146 | 277 297 407 537 567 637 857 1737 | 28 78 278 318 788 1836 | 199 609 749 849 999 1079 1389 2179 |

AMCP 706-177 Metriol Trinitrate (MTN) Liquid (or Trime+hylolethane Trinitrate)

| Composition: | Molecular Weight: (C-H9N309) | 255 |
|--|--|---------------------------------------|
| % C 23.5 O ₂ NO—CH ₂ | Oxyge Belence: CO ₂ % CO % | -35 - 3 |
| H 3.5 O_2NO-CH_2 $C-CH_3$ N 16.6 O_2NO-CH_2 | Density: gm/cc Liquid | 1.47 |
| 0 56.4 0 ₂ NO-CH ₂ | Molting Point: *C | -3 |
| 0 56.4 ² ² C/H Ratio 0.150 | Freezing Point: *C | · · · · · · · · · · · · · · · · · · · |
| Impact Sonsitivity, 2 Kg Wt: | Boiling Point: *C | |
| Bureau of Mines Apparatus, cm 47; (1 1b wt) 4 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg 20 | Refrective Index, n ¹¹ ₂₀ n ⁰ ₂₀ | 1.4752 |
| Friction Pendulum Test: Steel Shoe Explodes Fiber Shoe | Vecuum Stability Test: cc/40 Hrs, at 90°C | |
| Rifle Bullet Impact Test: Trials | 100°C cc/gm / 1.9 | |
| % Explosions | 135°C | |
| Partials | 150°C | |
| Burned | 200 Grem Bomb Sand Test: | |
| Unaffected | Sand, gm | ¹ 43.7 |
| Explosion Temperature: °C Seconds, 0.1 (no cop used) 1 5 Ignites 235 | Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl | |
| 15 20 | Ballistic Morter, % TNT: (a) | 136 |
| | Trouzi Test, % TNT: (b) | 140 |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: Method | |
| 100°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs 2.5 | Confined Density, gm/cc | |
| % Lrss, 2nd 48 Hrs 1.8 Explosion in 100 Hrs None | Brisonce, % TNT | |
| Flemmebility Index: | Detenation Rate: Confinement Condition | |
| Hygrescepicity: % 30°C, 90% RH 0.07 | Charge Diameter, in. | |
| | Density, gm/cc | |

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | | |
|--|--|-----------------|--|--|
| % mm HE, M71 Projectile, Let WC-91: | Glass Cones | Stret Cones | | |
| Density, gm/cc | Hole Volume | | | |
| Charge Wi, ib | Hole Depth | | | |
| Total No. of Fragments: | Color: Oilv. | -14-14-2 | | |
| For TNT | Orly, | slightly turbid | | |
| For Subject HE | Principal Uses: Ingredient of | of rocket and | | |
| 3 inch HE, M43A1 Projectile, Let KC-5: | double base | propellants | | |
| Density, gm/cc | | | | |
| Charge Wt, Ib | | | | |
| Total No. of Fragments: | Method of Looding: | | | |
| For TNT | | | | |
| For Subject HE | Leading Density: gm/cc | | | |
| Programm Velocity: ft/sec | - State of the sta | ÷. | | |
| At 9 ft At 25½ ft | Steroge: | | | |
| Density, gm/cc | Method | Liquid | | |
| Flust (Relative to TNT): | Hazard Ckss (Quantity-Dista | nce) | | |
| Air: | Compatibility Group | | | |
| Peck Pressure | | | | |
| Impulse | Exucation | | | |
| Energy: | | | | |
| Air, Cenfined: Impulse | Solubility in Water, gm/100 gm, at: | | | |
| | 25°C 60°C | < 0.015 | | |
| Under Weter: Peak Fressure | 60°C | <0.015 | | |
| Impulse | Heat of: | | | |
| Energy | Combustion, cal/gm | 2642 | | |
| Underground: | Hydrolysis, % Acid: | | | |
| Pecik Pressure | | A 43.0 | | |
| Impulse | 10 days at 22°C 5 days at 60°C | 0.018 0.115 | | |
| Energy | 22,5 20 30 0 | U-11) | | |
| | | | | |
| | | | | |
| | | | | |

Metriol Trinitrate (MTN) Liquid

Preparation:

Metriol (trimethylolmethylmethane) is obtained by the following procedure, based on work by flosseus (Annalen 276, 76 (1893):

Into a 5 liter round bottom flask is weighed 2700 gms of water. To this are added 267 gms of 36% formaldehyde and 60 gms of propionaldehyde. The mixture is stirred for a few seconds. To the mixture is added 150 gms of calcium oxide previously slaked with 600 gms of water. The mixture is heated in boiling water for four hours, and then allowed to cool spontaneously overnight. After filtering off the insoluble calcium hydroxide, the solution is heated and treated with a saturated aqueous solution of oxalic acid to precipitate all the calcium. The precipitated calcium oxalate is filtered off, and the pale-yellow filtrate concentrated as much as possible on the steam bath to a thick lemon-yellow syrup. After dissolving in absolute alcohol, the solution is filtered and concentrated in the steam bath to about twice the volume of the concentrated syrup. The solution is then chilled in a cold box to hasten crystallization. After allowing it to warm up to just above 0°C, the mixture is filtered. The resulting product is not sufficiently pure and is recrystallized from absolute alcohol. The melting point of the product (40.3 gm) is then about 196°C (Hosseus gives 199°C).

Metricl is nitrated by cerefully mixing it with 3.5 parts of 65/35 HNO₂/H₂SO₃ maintained at 20°C, stirring for 30 minutes, cooling to 5°C, and pouring the reaction mixture on ice. It is extracted with ether, water-washed, and adjusted to pH 7 by shaking with 3 sodium bicarbonate solution and again water-washed three times. It is then dried with calcium chloride, filtered, and freed of ether by bubbling with dry air until minimal rate of loss in weight is attained. The yield is 88% of the theoretical. The product has a nitrate-nitrogen content of 16.35% (calculated: 16.47%). Its refractive index at 25°C is 1.4752.

Origin:

MIN, according to Italian sources, was first prepared and patented by Bombrini-Parodi-Delfino Company of Italy under the name "metriolo." A German Patent of 1927 also describes the preparation and gives some properties. This compound was known in France before World Wax II under the name of "Nitropentaglycerin" and Burlot and Thomas determined its heat of combustion (Ref b).

References: 44

- (a) A. H. Blatt, Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1944.
 - (b) E. Burlot and M. Thomas, Mem poudr 29, 262 (1939).
- (c) Also see the following Picatinny Arsenal Technical Reports on Metriol Trinitrate: 1616 and 1817.

⁴⁴See footnote 1, page 10.

| Melecular Weight: | n | |
|---------------------------------------|---|--|
| Cxygen Belence: | | |
| | -38 | |
| CO 48 | -20 | |
| Density: gm/cc | 1.62-1.68 | |
| Melting Faint: 'C | | |
| Freezing Point: *C | | |
| Soiling Point: °C | | |
| Refrective Index, no | | |
| n _m | | |
| ng. | | |
| Vacuum Sephiller Tass | Petrological | |
| · - | | |
| 90°C | | |
| 100°C | | |
| 120°C | 2.1 | |
| 135°C | | |
| 150°C | | |
| 200 Georg Rough Sand Touts | | |
| Sond, gm | | |
| Sensitivity to Initiation: | | |
| Minimum Detonating Charge, | , gm | |
| Mercury Fulminate | | |
| Lead A zide | | |
| Tetryi | | |
| Beilistic Marter, % TNT: (a) | 143 | |
| | | |
| | | |
| | В | |
| | Pressed | |
| = = == | No No | |
| I | 1.73 | |
| , , , , , , , , , , , , , , , , , , , | 66 | |
| | | |
| (-) | Non e | |
| ***** | | |
| Charge Diameter, in. | Cast. 1.6 | |
| | 1 - [1 | |
| Density, gm/cc | 1.68 | |
| | CO. % CO % Density: gm/cc Melting Faint: "C Freezing Point: "C Refrective Index, no | |

| Pressed 100 1.46 | Oxygen, atoms/sec (Z/sec) Heat, kilocalorie/mole (ΔH, kcal/mol) |
|-------------------------|--|
| | Heat, kilocalorie/mole |
| 1.45 | (AH, kcgi/mol) |
| | N Company of the Comp |
| | Temperature Range, *C |
| 1.74 | Phase |
| (f) | Armor Plate Impact Test: (1) |
| • | |
| 1050 | 60 mm Morter Projectile: |
| | 50% Inert, Velocity, ft/sec 828 |
| | Aluminum Fineness |
| | 500-16 General Purpose Bembs: |
| | Plate Thickness, inches |
| _ | ויייניין די דיייניין די דיייניין די דיייניין די דיייניין די דיייניין דייניין דיינייין דיייין דייניין דייניין דייניין דייניין דיינייין דיינייין דייניין דייין דיינייין דייניין דייניין דייניין דיינייין דיייין דיינייין דיייין דיייין דיינייין דייייין דייייין דיינייין דייניין דיינייין ד |
| 1.74 | 1 |
| | 134 |
| | 11/4 |
| | 124 |
| | |
| | Somb Drop Test: |
| 16.5 x 10 ⁻¹ | 17, 2000-lb Semi-Armor-Piercing Bemb vs Concrete: |
| 1.74 | |
| | Sax Safe Drop, ft |
| | 500-le General Purpose Bemb vs Concrete: |
| | Heigh*, ft |
| | Trials |
| | Unaffected |
| | Low Order |
| 10 | High Order |
| 6 | |
| - | 1000-lb General Furpose Bomb v3 Concrete: |
| 1.66 | 11.15.6 |
| 1910-2070 | Height, ft Trials |
| | Unoffected |
| | == { |
| | Low Order |
| | High Order |
| | ₹ |
| | |
| | 0.30 1.74 (b) 16.5 x 10 ⁻¹ 1.74 |

Minol-2

| Glass Cones Steel Cones Hole Volume Hole Depth Celor: Gray Principal Uses: Bombs and depth charges Method of Leeding: Cast |
|---|
| Hole Volume Hole Depth Celer: Gray Principal Uses: Bombs and depth charges Method of Leeding: Cast |
| Color: Gray Principal Uses: Bombs and depth charges Method of Leeding: Cast |
| Principal Uses: Bombs and depth charges Method of Leeding: Cast |
| Principal Uses: Bombs and depth charges Method of Leeding: Cast |
| Method of Leeding: Cast |
| Method of Leeding: Cast |
| |
| |
| |
| |
| Applica Baseline and see 1 60 1 68 |
| |
| |
| Storege: |
| Method Dry |
| Hazard Class (Quantity-Distance) Class 9 |
| Compatibility Group Group I |
| |
| Exudation |
| |
| Preparation: |
| Minol is a castable mixture consisting of |
| 40 percent TNT, 40 percent ammonium nitrate. |
| and 20 percent powdered aluminum and there- fore can be prepared by adding the dry in- |
| gredients to molten TNT at 90°C under agita- |
| tion. Minol also can be prepared by adding 25 parts of aluminum to 100 parts of 50/50 |
| amatol previously prepared. |
| |
| |
| |
| |
| |

Origin:

Minols are British ternary explosives developed during World War II. There are three formulations:

| Composition, 5: | Minol-1 | Minol-2 | Minol-3 |
|------------------|---------|---------|------------|
| TMT | 48 | 40 | 42 |
| Ammonium Nitrate | 42 | 40 | 3 8 |
| Aluminum | 10 | 20 | 20 |

References: 45

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Emplosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1975.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) G. H. Messerly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Nate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, MOL Memo 10,303, 15 June 1949.
 - (f) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (g) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Technical Mv Lecture, 9 April 1948.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Minol-2: 1585 and 1635.

⁴⁵See footnote 1, page 10.

| Composition: | | Melecular Weight: | 40.6 |
|---|---------------------------------------|-------------------------------|---------|
| % Oxidizing apent (Armonium | | Oxygen Belence: | |
| Perchlorate) | 35.0 | CO. % | -44 |
| Aluminum, atomized | 26.2 | CO % | -37 |
| Cupric Oxide | | | |
| Magnesium, atomized | 26.2 | Density: gm/cc Pres | sed 2.0 |
| Other ingredient (Tetryl) | 9.7 | | |
| Calcium Stearate | 1.9 1.0 | Melting Point: °C | |
| Graphite, artificial C/H Rotio | 1.0 | Freezing Point: *C | |
| Impact Soncitivity, 2 Kg Wt: | | Boiling Point: °C | |
| Bureau of Mines Apparatus, cm | | | |
| Sample Wt 20 mg | | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. | 13 | n <u>s</u> | |
| Sample Wt, mg | 22 | | |
| | | n 🙀 | |
| Friction Pendulum Test: | | Vocuum Stability Test: | |
| Steel Shoe | Detonates | cc/40 Hrs, at | |
| Fiber Shoe | Unaffected | 90°C | |
| | | — 100°C | 0.47 |
| Rifle Sulfat Impact Test: Trials | | 120°C | |
| % | | 135°C | |
| Explosions | | 150°C | |
| Partials | | 150°C | |
| Burned | | 200 Grem Bomb Sand Test: | |
| | | | 10.6 |
| Unaffected | · · · · · · · · · · · · · · · · · · · | Sand, gm | |
| Explosion Temperature: 'C | | Sensitivity to Initiation: | |
| Seconds, Q.1 (no cop used) | | Minimum Detonating Charge, gr | n |
| 1 | | Mercury Fulminate | |
| 5 285 | | Leod Azide | 0.20 |
| 10 | | Tetryi | 0.25 |
| 15 | | l esry: | |
| 20 | | Sallistic Merter, % TNT: | |
| | | Treuzi Test, % TNT: | |
| 75°C International Hos? Test: | | Plate Dent Test: | |
| % Loss in 48 Hrs Discoloration, fumes, odor | None | Method | |
| | -14-14 | Condition | |
| 100°C Heat Yest: | | | |
| % Loss, 1st 48 Hrs | 0.10 | Confined | |
| % Loss, 2nd 48 Hrs | 0.01 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| | | Detonation Rate: | |
| Flammability Index: | | Confinement | |
| | | | |
| Hygrescopicky: % | | Condition | |
| TITEL TO | | Charge Diameter, in. | |
| | | | |
| Volatility: | | Density, gm/cc | |

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 10 | 0: |
|---|---|---------------------------|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Co Hole Volume Hole Depth | pnes |
| Total No. of Fragments: For TNT | Color: Gray powder mixture | |
| For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb | Principal Uses: Small caliber ant: projectiles | laircraft |
| Total No. of Fragments: For TNT | Method of Loading: | Pressed |
| For Subject HE Fregment Velocity: ft/sec | Leeding Deasity: gm/cc At 30,000 psi | ~ 2.0 |
| At 9 ft At 25½ ft Density, gm/cc | Sterege: Method | Dry |
| liest (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 |
| Air: Peak Pressure Impulse Energy | Compatibility Group Bureau of Explosives Classific Exudation | Group I cation Class A |
| Air, Confined: Impulse Under Weter: Peak Pressure Impulse | Heat of: Combustion, cal/am Explosion, cal/gm Gas volume, cc/gm Performance Tests: | 4087 2087 212 |
| Energy Underground: Peak Pressure | 20 mm T215El Projectile: NFOC Pressure Cube APG Blast Cute Activation Energy: | 35 40 |

| Composition: | | Molecular Vielght: | 42 |
|---|--------------------|--|-------------|
| Oxidizing agent (Ammonium Perchlorate) Aluminum, atomized | 35.0 52.4 | Oxygen Belence: CO ₂ % CO % | -4 ? -43 |
| Cupric Oxide Magnesium, atomized | | Density: gm/cc Pressed | 2.0 |
| Other ingredients* Calcium Stearate | 9.7 1.9 | Molting Point: *C | |
| Graphite, artificial *5.8% RMX and 3.9% TNT coated po | 1.0 n Appropium | Freezing Point: °C | |
| Impact Sensi wity, 2 Kg Wt: | cinora ce. | Beiling Point: °C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. | 12 | n _m | |
| Somple Wt, mg | 24 | n _{ss} | |
| Friction Pondulum Test: | | Vacuum Stability Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Fiber Shoe | Unaffected | 90°C | |
| Rifle Bullet Impact Test: Trials | | 100°C | 0.21 |
| · | | 120°C | |
| % Explosions | | 135°C | |
| Portials | | 150°C | |
| Burved | | 200 Gram Bomb Sand Test: | |
| Unoffacted | | Sand, gm | 11.5 |
| Explosion Temperature: *C Seconds, 0.1 (n. csp used) | | Sensitivity to Initiation: Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 375 | | Lead Azide | 0.20 |
| 10 | | Tetryl | 0.20 |
| 15 | | | |
| 20 | | Ballistic Morter, % TNT: | |
| 73°C International Heat Test: | | Trougi Test, % TNT: | |
| % Loss in 48 Hrs Discoloration. fumes, odor | None | Plate Dest Test: Method | |
| 100°C Heet Test: | | Condition | |
| % Loss, 1st 48 Hrs | 0.27 | Confined | |
| % Loss, 2nd 48 Hrs | 0.12 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TN1 | |
| Flammability Index: | | Detenation Rate: Confinement | |
| Hygruscopicity: % | | Condition Charge Diameter, in. | |
| Veletility: | | Density, gm/cc Rate, meters/second | |

| Fragmentativa Test: | | | Shaped Charge Effectiveness, TNT = 100: | | |
|---|---------------|--------------|---|---------------------------------------|--|
| 90 mm HE, M71 Projectil Density, gm/cc Charge Wt, ib | e, Let WC-91 | : | Glass Cones Steel Cones Hole Volume Hole Depth | | |
| Total No. of Fragments: For TNT | : | | Color: | Gray | |
| For Subject HE | | | Principal Uses: HE filler for small c | -145 | |
| 3 inch HE, M42A1 Project Density, gm/cc Charge Wt, Ib | ile, Let KC-5 | : | projectiles | atioar | |
| Total No. of Fragments: For TNT | | | Method of Loeding: | Pressed | |
| For Subject HE | | | Leeding Density: gm/cc | 2.0 | |
| Fragment Velocity: ft/sec At 9 ft At 251/2 ft | | | Storage: | · | |
| Density, gm/cc | | | Method | Dry | |
| Blast (Relative to TNT): | | | Hazard Class (Quantity-Distance) | Class 9 | |
| Air: Bare Charge: | EW* | EV# 1.34 | Compatibility Group Bureau of Explosives Class A | Group I | |
| Impulse | 1.08 | 1.41 | Exudation | None | |
| Energy Density, gm/cc Air, Conflact: Impulse | | 1.96 | Heat of: Combustion, cel/gm | fr:8# | |
| Cased Charge in Air:* | * | | Explosion, cal/gm Gas volume, cc/gm | 14,72 22 | |
| Peak Pressure Impulse | 1.09 1.16 | 1.44 1.53 | Performance Tests: | | |
| Energy Density, gm/cc | | 1.98 | 20 mm T215E1 Projectile: | 29 | |
| Underground: Peak Pressure | | | APG Blest Cube | 30 | |
| impulse | | | Aviation Energy: | | |
| *EW, equivalent weight EV, equivalent volume | | | kcel/mol Temp, CC 340 Time to ignition, seconds 1.3 | 7.6 to 470 9 x 10 ⁻² | |
| **Strong paper-base phe | • | | | | |

Effect of Altitude, Charge Diameter and D. Gree of Confinement on Detonation Velocity* (Reference g)

| | One-In | ch Column | Two-Inch | Column | |
|-----------------------------|------------------|-------------------|---------------------------------|----------------------------|------------|
| Simulated Altitude, Feet | Confined m/s | Unconfined m/s | Confined m/s | Unconfined m/s | |
| Cround | | | 4730 | | |
| 30,000 | Charge would not | | 90,000 Charge would not 4530(3) | 4530(3) | Charge wou |
| 60,000 | propugate | detonation. | 14430 | not propa- gate detona- | |
| 90,000 | • | | 4290 | tion. | |
| Average | • | | 4495 | | |

^{*}Confined charge in 1/4" steel tube. AISI 1015 seemless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetryl booster was used to initiate each charge.

Average Fragment Velocity at Various Altitudes* (g)

| | 1 | Sin | | | t |
|---------------------|------------------|--------|--------|--------|-----------------|
| Explosive | Charge Diameter, | Ground | 30,000 | 60,000 | <u>; 90,000</u> |
| | Inches | m/s | m/s | m/8 | .√s |
| MOX-2B, density, | 1 | 2012 | ** | ** | ** |
| gm/cc 207 | 2 | 3314 | 3351 | 3247 | ** |

^{*}Outside diameter 2.54"; inside diameter 2.04"; length 7".

^{**}Charge would not propagate detonation.

| Composition: | | Melecular Weight: | 45.6 |
|--|------------|--------------------------------|------------|
| Oxidizing agent (Potassium Ni | trate) 18 | Oxygen Belence: | |
| Aluminum, atomized | 5 0 | CO. % | -52 |
| Cupric Cxide Magnesium, atomized | | CO % | -52 -43 |
| Other ingredients* | 32 | | |
| Culcium Stearate** | 2.0 | Density: gm/cc Pressed | 2.0 |
| Graphite, artificial** | 1.0 | Melting Point: °C | |
| *29.1% RDX, 0.9% wax, and 2. **Per cent added. | 0% TNT. | | |
| | | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | •• | Boiling Point: *C | |
| Sample Wt 20 mg | 17 | Refrective Index, no | |
| Picatinny Arsena! Apparatus, in. Sample Wt, mg | 17 24 | n _R | |
| Sumple Wt, mg | 24 | ກລື | |
| Friction Pendulum Test: | | Vocuum Stebility Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Fiber Shoe | Unaffected | 90°C | |
| | | - 100°C | 0.57 |
| Rifle Bullet Impact Test: Trials | | 120°C | 2.51 |
| 96 | | | |
| Explosions | | 135°C | |
| Partials | | 150°C | |
| Burned | | 200 C P C 4 T 1 | |
| Unaffected | | 200 Grem Bomb Sand Tost: | |
| Ungrected | | Sand, gm | 33.2 |
| Explosion Temperature: 'C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) | | Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 540 | | Lead Azide | 0.20 |
| 10 | | Tetryi | 0.15 |
| 15 | | Belli .: Morter, % TNT: | |
| 20 | | Trougi Test, % TNY: | |
| 75°C International Host Test: | | Plate Dent Test: | |
| % Loss in 48 Hrs Discoloration, fumes, odor | None | Method | |
| | 110116 | Condition | |
| 100°C Heat Test: | 0.35 | Confined | |
| % Loss, 1st 48 Hrs | 0.35 | Density, gm/cc | |
| % Loss, 2nd 48 Hrs | 0.13 | | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| Flammability Index: | | - Detenation Rate: Confinement | |
| | | | |
| Hygrescopicity: % | | - Condition | |
| , g | | Charge Diameter, in. | |
| | | | |
| Veletility: | | Density, gm/cc | |

| Fregmentation Test: | Shaped Charge Effectiveness, TNT == 100: | | |
|--|--|---|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Con | es Steel Cones | |
| Density, gm/cc | Hole Volume | | |
| Charge Wt, Ib | Hole Depth | | |
| Total No. of Fragments: | Color: Gi | ray powder mixture | |
| For TNT | Com: 0. | ay powder mixture | |
| For Subject HE | Principel Uses: Small ca | aliber antimircreft | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | projecti | les | |
| Density, gm/cc | | | |
| Charge Wt, Ib | | | |
| Total No. of Fragments: | Method of Leading: | Pressed | |
| For TNT | | 110000 | |
| For Subject HE | | | |
| | Looding Density: gm/cc | | |
| Fragment Velocity: ft/sec | At 30,000 psi | ~2.0 | |
| At 9 ft At 25½ ft | Storage: | | |
| Densit/, gm/cc | | | |
| | Method | Dry | |
| Blast (Relative to TNT): | Hazard Class (Quantity-I | Distance) Class 9 | |
| Air: | Compatibility Group | Group I | |
| Peak Pressure | Bureau c | of Explosives Class A | |
| Impulse | | | |
| Energy | | | |
| Air, Confined: | Heat of: | | |
| Impulse | Combustion, cal/gm | ı 4331 | |
| 44 4 344 . | Explosion, cal/gm | | |
| Under Weter: Peak Pressure | Gas volume, cc/g | gm 232 | |
| Impulse | Performance Tests: | | |
| Energy | 20 mm T215El Proje | ctile: | |
| Undergreund: Peak Pressure | NFOC Pressure Cube APG Blast Cube | 37 52 | |
| Impulse | Activation Energy: | | |
| Energy | | | |
| - - | kcal/mol Temp, C | Values not included | |
| | Temp, C Time to ignition, | due to erratic ig- nition under condi- | |
| | seconds | tions of test. | |
| | | | |
| | | | |
| | | | |

| Composition: | | Melecular Weigin: | F 8 |
|---|--|--|------------|
| Oxidizing agent (Barium Nitret Aluminum, atomized Cupric Oxide Magnesium, atomized | 18 50 | Oxygen Belence: CO ₂ % CO % | -53 -43 |
| Other ingredients* Calcium Stearate** | 32 2.0 | Density: g: //cc Pressed | 2.0 |
| Graphite, artificial** *29.1% RDX, 0.9% wax, and 2.0 **Per cent added. | 1.0 d TNT. | Malting Point: "C Freezing Point: "C | |
| Impact Scasitivity, 2 Kg Wt: | -0 | Boiling Point: °C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | 78 18 26 | Refrective Index, no | |
| Friction Pendulum Yest: Steel Shoe Fiber Shoe | Sparks Unaffected | Vecuum Stability Test: cc/40 Hrs, at 90°C | |
| Rifle Bullet Impact Test: Trials Explosions Partials | | 100°C 120°C 135°C 150°C | 0.67 |
| Burned Unoffected | | 200 Grem Bomb Sand Test: Sand, gm | 33.6 |
| Explosion Temperature: *C Seconds, 0.1 (no cap used) 1 5 610 | a a marin a ma | Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide | 0.20 |
| 15 20 | | Tetryl Bellistic Morter, % TNT: | 0.15 |
| 75°C International Heat Test: % 1:3s in 48 Hrs Discoloration, fumes, odor | None | Plate Dent Test: Method | |
| 180°C Heet Test: % Loss, ist 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs | 0.22 0.12 None | Condition Confined Density, gm/cc Brisance, % TNT | |
| Flammability index: | | - Detenation Rate: Confinement | |
| Hygroucopicity: % | | Condition Charge Diameter, in. | |
| Veletility: | | Density, gm/cc Rate, meters/second | |

MCX-4B

| Fragmantstion Test: | Shaped Charge directiveness, TNT = 100: | | | | |
|---|--|---|--|--|--|
| 90 mm HE, M71 Prejectl > Let WC-91: Density, gm/cc | Glass Cones Hole Volume | Steel Cones | | | |
| Charge Wt, Ib | Hole Depth | | | | |
| Total No. of Fragments: For TNT | Color: | Gray powder mixture | | | |
| For Subject HE 3 inch HE, M42A1 Project Let XC-3: Density, gm/cc Charge Wt, Ib | Principal Usa: Small caliber entiaircraft projecules | | | | |
| Total No. of Fragments: For TNT For Sub, act HE | Merhod of Localing: | Pressed | | | |
| Fragment Velocity: ft/sec | Leeding Density: gm/cc At 30,000 psi | ~ [/ 0 | | | |
| At 9 ft At 251/ ₃ ft | Storage: | | | | |
| Density, gm/cc | Method | Dies | | | |
| Blass (Relative to TNT): | Hozard Class (Quantity-Dis | tance) Class 9 | | | |
| Air: Peak Pressure Impulse Energy | Compatibility Group | Group I Bureau of Explosives Class A | | | |
| Air, Confined: Impulse Lader Weter: Peak Pressure Impulse Energy | Commustion, cal/gm Explosion, cal/gm Gas volute, cc/gm Performance Tests: 20 mm T215E1 Project | 4392 709 208 11e: | | | |
| Underground: Peak Pressure impulse | NFOC Pressure Cube APG Blast Cube Aviation Energy: | 43 53 | | | |
| Energy | kcel/mol Temp, C Time to ignition, seconds | Values not included due to erratic ignition under conditions of test. | | | |

| Composition: | | Molecular Weight: | 43 |
|----------------------------------|--------------|-------------------------------|--------------|
| Oxidizing agent | | Oxygen Belence: | |
| Aluminum, atomized | 49.2 | CO. % | 50 |
| Cupric Oxide | 19.7 | CO % | -50 -42 |
| Magnesium, at mized | | | -42 |
| Other ingredients* | 29. 6 | Density: gm/cc | |
| Calcium Stearate | | | |
| Graphite, artificial | 1.5 | Melting Point: °C | |
| *28.7% RDX coated, 0.9% wax. | | | |
| C/H Ratio | | Freezing /oint: *C | |
| Import Sensitivity, 2 Kg Wt: | | Boiling Point: °C | |
| Bureau of Mines Apparatus, cm | 78 | | |
| Sample Wt 20 mg | | Refractive Index, no | |
| Picatinny Arsenal Apparatus, in. | 19 | | |
| Sample Wt, mg | 27 | n _S | |
| | | i n ₂₀ | |
| Friction Pendulum Test: | | Vacuum Stebility Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Fiber Shoe | Unaifected | 90°C | |
| | | 100°C | 0.43 |
| Rifle Bullet Impact Test: Tricls | | | 0.43 |
| % | | 120°C | |
| Explosions 70 | | 135°C | |
| Portials | | 150°C | |
| Burned | | | |
| | | 200 Gram Bomb Sand Test: | |
| Unaffected | | Sand, gm | 10. 8 |
| Explosion Temps ature: 2C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, ym | |
| 1 | | | |
| 5 510 | | Mercury Fulininate | |
| - /10 | | Lead Azide | 0.20 |
| 10 | | Tetryi | 0.16 |
| 15 | | Bellinia Manage W. 11/2 | |
| 20 | | Sallistic Morter, % 167: | |
| 75°C International Heat Test: | | Trauzi Test, % TNT: | |
| Loss in 48 Hrs | 0.02/10 gm | Flate Dent Test: | |
| Discoloration, fumes. odor | None | Method | |
| 109°C Heat Test: | | Condition | |
| % Loss, 1st 48 Hrs | 0.00 | Confined | |
| Co Loss, 2nd 48 Hrs | 0.00 | Density, gm/cc | |
| • | | Brisance % TNT | |
| Explosion in 100 Hrs | None | | |
| | | Detenation Rate: | |
| Flammahility Inday | | | |
| Flammability Index: | | Confinement | |
| | | Condition | |
| Tygroscopicity: % | 0.79 | | |
| | 0.79 | Condition | |

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MOX-6B

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | | | |
|--|---|--|--|--|--|
| 90 mm HC, M71 Projectile, Lct WC-91: Density, gm/cc Charge Wt, lb Total No. of Fragments: | Glass Cones Steel Cones Hole Volume Hole Depth | | | | |
| For TNT For Subject HE | Color: Gray powder mixture | | | | |
| 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: Small caliber antiaircraft projectiles | | | | |
| Total No. of Fragments: For TNT | Method of Leading: Pressed | | | | |
| For Subject HE Fregment Velocity: ft/sec At 9 ft At 25½ ft | Looding Density: gm/cc At 30,000 psi ~2.0 Storage: | | | | |
| Density, gm/cc | Method Dry | | | | |
| Black (Relative to TNT): | Hazard Class (Quantity-Distance) Class 9 | | | | |
| A ir: Peak Pressure Impulse Energy | Compatibility Group Grop I Bureau of Explosives Class A | | | | |
| Air, Confined: Impulse Under Weter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy | Combustion, cal/gm 4293 Explosion, cal/gm 750 Gas volume, cc/gm 204 Activation Energy: kcal/mol Values not included temp, C due to erratic ignitime to ignition, seconds of test. | | | | |

MOX-1; MOX-2B; MOX-3b; MOX-4B; MOX-6B

Preparation:

The various ingredients used in the preparation of MOX explosives are coated separately as follows:

Dichromated Atomized Aluminum - Seventy-five grams of chemically pure grade sodium dichromate is dissolved in 1500 milliliters of water at 100°C under mechanical agitation. Six hundred grams of the atomized aluminum powder is added gradually (2 to 3 minutes) and stirring is continued for half an hour. The dichromated metal is filtered, washed with water (15 to 20 times) until the washings show only a slight cloudiness with silver nitrate. The water-wet product is then dried in an oven at 50°C. The dried material is hand-rolled to reduce any conglomerates, and blended before use.

Wax-Coated RDX - Eighteen grams of molten Be Square Special Wax (manufacturer : 180° to 185° Fahrenheit grade amber) is added to 582 grams of finely divided RDX (water precipitated from acetone solution) in a water slurry under mechanical agitation. The temperature of the wax-RDX slurry is maintained above the melting point of the wax (about >0°C). The stirring is continued for half an hour. After cooling to 50°C, the wax-coated RDX is recovered by filtration in a Büchner funnel and dried in air. The RDX thus coated and presumed to be 3% waxed RDX or a 97/3 RDX/wax mixture is hend-rolled to crush any conglowerates formed, and bleuded by hand before use.

INT-Coated Barium Nitrate - Thirty grams of INT in alcohol solution is added to 270 grams of barium nitrate in an alcohol slurry under sgitation. The temperature of the INT-barium nitrate mixture is maintained at 80°C and stirring is continued until most of the alcohol is evaporated. The coated material is spread in a thin layer on a tray to dry in air overnight. The barium nitrate thus coated with 10% INT is reduced to an intimate mixture by hand-rolling and blending before use.

INT-Coated Potassium Nitrate - The INT-coated potassium nitrate is prepared by the same procedure as is used for coating barium nitrate.

ADX/INT-Coated Ammonium Perchlorate - The ammonium perchlorate is coated by dissolving the appropriate weights of RDX and INT in hot; cohol. After add. the ammonium perchlorate, the ivery is stirred until most of the solvent is evaporated. The treated ammonium perchlorate spread on a tray to dry overnight. Agglomerates formed during the process are crushed by band-rolling and blending the mixture before use.

TMT-Coated RDX - Sixty grams of rolten TMT are added to a water slurry of 540 grams of finely divided RDX (water precipitated from acetone solution) under mechanical agitation. The temperature of the TMT-RDX slurry is maintained at about 90°C and stirring is continued for helf an hour. After cooling to about 50°C, the TMT-coated RDX is recovered by filtration. The RDX thus treated, and presumed to be 10% coated or a 90/10 RDX/TMT mixture, is further blended by hand after rolling to crush any aggregates formed during the process.

The MOX explosive mixtures are prepared by blending the appropriate weights of the dry ingredients in a Patterson-Kelly twin-shell blender for at legst 30 minutes.

Origin:

MOX type explosive mixtures were developed beginning in 1950 by National Northern, technical division of the National Fireworks Ordnance Corporation, West Hanover, Massachusetts.

References: 46

- (a) A. O. Mirerchi and A. T. Wilson Development of MOX Explosives for Improved 20 mm Ammunition, Navy Contract Nord-10975, Task 1, National Fireworks Ordnance Corporation: First Yearly Summary, August 1950 to August 1951.
- (b) A. T. Wilson, Development of MOX Explosives: Various Oxidants in MOX, First Progress Report NFOC-6, Navy Contract Nord-12382, National Fireworks Ordnance Corporation, December 1952.
- (c) A. O. Mirarchi, Properties of Explosives: Theory of the MOX Explosion, First Progress Report NFOC-10, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, December 1952.
- (d) A. O. Mirarchi, Properties of Explosives, MOX Explosives in Various Atmospheres, First Progress Report NFOC-9, Navy Contract NOrd-11393, National Fireworks Ordnance Corporation, 1952.
- (e) A. T. Wilson, Development of MCX Explosives: Composition Variations, First Progress Report NFOC-7, Navy Contract NOrd-12382, National Fireworks Ordnance Corporation, 1952.
- (f) A. T. Wilson, <u>Development of MOX Explosives: Various Oxidants in MOX</u>, Second Progress Report NFOC-14, Navy Contract NOrd-13684, National Fireworks Ordnance Corporation, October 1953.
- (g) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, Detonation Velocity Determinations and Fragment Velocity Determinations of Varied Explosive Systems and Conditions, National Northern Corporation Final Summary Report NNC-F-13, February 1958 (Contract DAI-19-020-501-0RD-(P)-58).
- (h) P. Z. Kalanski, Air Blast Evaluation of MOX-2B Cased and Bare Charges, NAVORD Report No. 3759, 5 April 1956.
- (i) Also see the following Picatinny Arsenal Technical Reports on MOX Explosives: 1935, 1969, 2204. 2205.

⁴⁶See footnote 1, p.

Nitrocellulose, _2.6% (NC)

| Composition: | Malecular Weight: (272.39) | 1 | | | |
|--|--|---|--|--|--|
| % C 26.46 H 2.78 N 12.60 X H X H | Orygen Falence: CO: % -35 CO % 0.6 | | | | |
| 0 58.16 0 x | Density: gm/cc | | | | |
| н | Melting Point: °C Decomposes | | | | |
| C/H Ratio 0.23 | Freezing Point: *C | | | | |
| Impact Sensitivity, 2 Kg Wt: Rurenu of Mines Apparatus cm 8 | Boiling Point: 'C | | | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5 | Refractive Index, no no no | | | | |
| Friction Pendulum Test: Steel Shoe Filter Shoe | Vecuum Stability Test: cc/40 Hrs, at 90°C 0.17 | | | | |
| Rifle Bullut Impact Test: Trials % Explosions Partials | 100°C 1.0 120°C 16 hours 11.+ 135°C 150°C | | | | |
| Burned Unaffected | 200 Grem Bomb Sand Test: Sand, gm 45.0 | | | | |
| Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Decomposes 170 10 | Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide O.10 Tetryl | | | | |
| 15 20 | Ballistic Morter, % TNT: | | | | |
| | Trouzi Test, % TNT: | | | | |
| 75°C International Heat Test: % Loss in 48 Hrs 100°C Heat Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs | Plete Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT | | | | |
| Explosion in 100 Hrs Flammability Index: | Detenotion Rete: Confinement | | | | |
| Hygroscopicity: % 30°C, 90% RH 3 | Condition Charge Diameter, in. Density, gm/cc | | | | |
| Volatility: 60°C, mg/cm²/hr 0.0 | Rate, meters/second | | | | |

Nitrocellulose, 13.45% N (NC)

| emposition: H o | Melecular Weight: | (£86.34) _n |
|--|-----------------------------|-----------------------|
| c 25.29 | Oxygen Belance: | |
| H 2.52 R ₂ C | CO ₂ % | -29 4.7 |
| N 13.45 X " H O " H | Density: gm/cc | |
| X=0NO ² | Melting Point: "C | Decomposes |
| C/H Ratio 0,23 | Freezing Point: °C | |
| mpact Sensitivity, 2 Kg Wt: | Soiling Point: *C | |
| Bureau of Mines Apparatus, cm 9 Sample Wt 20 mg | Refrective Index, nº | |
| Picatinny Arsenal Apparatus, in. 3 | n _s | |
| Sample Wt, mg 5 | n _{so} | |
| Friction Pendulum Test: | Yecuum : 'Ility Test: | |
| Steel Shoe | cc/40 H.s, at | of ho |
| Fiber Shoe | 90°C | 0.42 |
| Riffe Bullet Impact Test: Trials | 100°C | 1.5 |
| % | 120°C | 11.+ |
| Explosions | 135°C | |
| Partials | 150°C | |
| Burned | 200 Gram Somb Sand Test: | |
| Unaffected | Sand, gm | 49.0 |
| Explosion Temperature: °C | Secusitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge | , sim |
| 1 5 230 | Mercury Fulininade | |
| 10 | Lead Azide | 0.10 |
| 15 | Tetryl | |
| 26 | Bellistic Morter, % INT: | 125 |
| | Trouzi Test, % TNT: | |
| 75°C Internetional Heat Test: % Loss in 48 Hrs | Plate Dent Test: | |
| | Method | |
| 1v0°C Heat Test: | Condition . | |
| % Loss, 1st 48 Irs 0.3 | Confined | |
| % Loss, 2nd 48 Hrs 0.0 | Density, gm/cc | |
| Explosion in 100 Hrs None | Brisance, % TNT | |
| Flommability Index: | Detenation Rate: | |
| | Condition | |
| Hygrescopicity: % 30°C, 90% RH ~ 2 | Charge Diameter, in: | |
| Veletility: 60°C, mg/cm²/nr 0.0 | Density, gm/cc | 1.20 |
| | | |

| Composition: | Molecular Weight: (297-15) _n |
|--|--|
| % C 24.25 H 2.37 N 14.14 H 2 C H X | Oxygen Belence: CO ₂ % -24 CO % 6 |
| 0 59.24 0 H | Density: gm/cc 1.65-1.70 |
| X n | Melting Point: °C Decomposes |
| C/H Ratio 0.23 | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: Burgau of Mines Apparatus, cm 8 | Boiling Point: °C |
| Sample Wt 20 mg | Refractive Index, 1120 |
| Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 5 | n 🖁 |
| | n _{so} |
| Friction Pendulum Test: | Vocuum Stability Test: |
| Steel Shoe | cc/40 Hrs, at |
| Fiber Shor | 90°C 1.46 |
| Rifle Bullet Impact Test: Trials | |
| % | |
| Explosions | 135 °C 150°C |
| Partials | 157 C |
| Burned | 200 Gram Bomb Sand Test: |
| Unaffected | Sand, gm 52.3 |
| Explosion Temperature: °C | Sensitivity to Initiation: |
| Seconds, 0.1 (no cap used) | Minimum: Detonating Charge, gm |
| 1 | Mercury Fulminate |
| 5 | Leod Azide C-10 |
| 10 | Tetryl |
| 15 20 | Bellistic Mortus, % TNT: |
| 20 | Trauxi Test, % TNT: |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: |
| 70 LOSS III 40 FIIS | Method |
| 100°C Heat Test: | Condition |
| % Loss, 1st 48 Hrs | Confined |
| % Loss, 2nd 43 Hrs | Density, cm/cc |
| Explosion in 100 Hrs | Brisance, % TNT |
| | Detenation Rate: |
| Flammability Index: | Confinement |
| Hygroscopicity: % 30°C, 90% RH | Condition |
| Hygrescopicity: % 30°C, 90% RH ~ 1 | Charge Diameter, in: |
| Voletility: 60°C, mg/cm²/hr 0.0 | Density, gm/cc |
| | Rate, meters/second |

Nitrocellulose (NC)

| Fragmentation Test: | Sheped Charge Effectiveness, TNT = 100: | | | |
|--|--|---|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc | Glass Cones Steel Cones Hole Volume | | | |
| Charge Wt, Ib | Hole Depth | | | |
| Total No. of Fragments: | Color: | White | | |
| For TNT | | | | |
| For Subject HE | Principal Uses: Pyroxylin | | | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | cellulose (12.60% N), guncotton (13.35% N | | |
| Density, gm/cc | minimum), propell | | | |
| Charge Wt, ib | ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, | | | |
| Total No. of Fragments: | Method of Looding: | | | |
| For TNT | | | | |
| For Subject HE | Loading Density: gm/cc | | | |
| P. Common M. B. Charles | | | | |
| Fragment Valuelty: ft/sec At 9 ft | | | | |
| At 251/2 fr | Storuge: | | | |
| Density, gm/cc | | | | |
| | Method | Wet (8% to 30% water) | | |
| Bleet (Reletive to TNT): | Hozard Class (Quantity-Distance) Class 12 | | | |
| Air: | Compatibility Group | Group M | | |
| Peak Prescure | , - , | (wet) | | |
| Impulse | Exudation | None | | |
| Energy | | | | |
| Air, Confinct | Heat of: | | | |
| Impulse | Combustion, cal/gm 2409 | | | |
| | Explosion, cal/gm 855 Cas Volume, cc/gm 919 | 5* 965 ** 1058 *** 5* 883 ** 853 *** | | |
| Under Weter: Peak Pressure | | * 561** 513*** | | |
| Impulse | * 12.6% N | | | |
| Energy | ** 13.45% N *** 14.14% N | | | |
| Underground: Peok Pressure | Vapor Pressure: | | | |
| Impulse | °c | mm Mercury | | |
| Energy | | | | |
| ~ '' Y | 25 60 | 0.00 | | |
| | 60 | 0.00 | | |
| | | | | |
| | | | | |

Nitrocellulose (NC)

| Solubility in Water, gm/100 gm, at: | 12.6% N | 13.45% N | 14.0% N |
|--|-----------------------------------|---------------------------------|-------------------------------|
| 25°C 60°C | Insoluble Insoluble | Insoluble Insoluble | Insoluble Insoluble |
| Solubility, gm/100 gm, 25°C, in: | | | |
| Ether Alcohol | Insoluble Very slight- ly soluble | Insoluble Practically insoluble | Insoluble Insoluble |
| 2:1-Ether:Alcohol | Soluble | Slightly soluble (6%-11%) | Practically insoluble (1 + 2) |
| Acetone | Soluble | Soluble | Soluble |
| 24)-Hour Hydrolysis Test, 5 Mitric Aci. | 1.22 | 1.03 | |

Preparation of Nitrocellulose from Cotton Linters: (Imboratory Procedure)

Mitration: Second cut cotton linters, previously dried to a moisture content of less than 0.5%, are nitrated by immersion in mixed acid under the following conditions:

Ratio of Mixed Acid to cotton 55 to 1

Composition of Mixed Acid (approximate)

- a. for 12.6% N: H_2SO_4 63.5%, HNO_3 21%, H_2O 15.5%
- b. for 13.4% N: H₂SO₄ 68%, HNO₃ 22%, H₂O 10.0%

Temperature of acid at the start

34°C

Time of nitration

24 minutes

During the nitration period the mixture is turned over occasionally to keep the acid homogeneous. The mixture is then filtered on a Buchner funnel with suction for about three minutes and then drowned rapidly with strong hand stirring in at least 50 volumes of cold water. After the nitrocellulose has settled, most of the water is decanted and fresh water added. The nitrocell lose-water mixture is boiled and the acidity adjusted to 0.25% to 0.50% as $\rm H_2SOl_1$. The sour boil is continued for at least 24 hours for pyrocellulose and at least 40 hours for gun-cotton. Additional boiling with changes of water are made in accordance with the governing specification (JAN-N-244).

<u>Pulping:</u> The nitrocellulose is then pulped in a laboratory Holland type paper beater. Enough sodium carbonate is added to keep the reaction faintly alkaline to phenolphthalein. Pulping is continued to the desired degree of fineness.

Posching: After washing the nitrocellulose from the beater, the mixture is filtered and the product boiled for 4 hours with fresh water while stirring mechanically. From time to time a little codium carbonate solution is added to maintain the mixture faintly alkaline to phenolphtbalein. The water is decanted and the boiling continued. According to the specification, the total boiling treatment with poachi. is as follows:

Nitrocellulose (NC)

- 4 hours boiling with or without sodium carbonate
- 2 hours boiling without sodium carbonate
- 1 hour boiling without sodium carbonate
- 1 hour boiling without sodium carbonate.

Each boil is followed by settling and change of water.

Washing: The nitrocellulose is then washed by mechanical agitation with water. A minimum of two washes are given. If a sample taken after the water washes gives a minimum test of 35 minutes in the 65.5°C Heat Test and 30 minutes in the 134.5°C Heat Test, the nitrocellulose is satisfactorily stabilized. Otherwise additional washes should be given.

Origin:

Cellulose occurs in nature. It is wood fiber, cell wall and the structural material of all plants. Cotton fiber is pure cellulose. Nitrocellulose was discovered about 1847 by C. F. Schonbein at Basel id R. Bettger at Frankfort-on-the-Main independently of each other when cotton was nitrated. T. J. Pelouze had nitrated paper earlier (1838) and was probably the first to prepare nitrocellulose.

Pyroxylin or collodion, which is soluble in a mixture of ether and ethanol, contains from 8% to 12% nitrogen. It is used in the manufacture of celluloid and in composite blasting explosives.

Pyrocellulose, a type of nitrocellulose of 12.6% nitrogen content, comp. 'y soluble in a mixture of 2 parts ether and one part ethanol, was developed by Mendeleev (.1-1895). This material, when colloided, formed the first smokeleus powder for military use in the United States (1898).

Guncotton for military purposes they contains a minimum of 13.35% nitrogen. It is only slightly soluble in ether-ethanol, but completely soluble in acetone. Principal use is in flashless powders and as rlame carriers. 14.14% N nitrocellulose represents a theoretical limit.

In the manufacture of propellants, there is used a mixture of pyrocellulose and guncotton (blooded nitrocellulose) of 15.15% to 13.25% nitrogen content.

restruction by Chemical Decomposition:

Nitrocellulose is decomposed by adding it, with stirring, to 5 times its weight of 10% sodium hydroxide heated to 70°C. Stirring is continued for 15 minutes after all the nitrocellulose bas been added.

References: 47

(a) See the following Picatinny Argenal Technical Reports on Nitrocellulose:

⁴⁷See fostnote 1, page 10.

Nitrocellulose (NC)

| <u>o</u> | <u>1</u> | 2 | <u>3</u> | <u>4</u> | 2 | <u>6</u> | 7 | <u>8</u> | 2 |
|---|---|--|--|---|---|--|--|--|---|
| 10 390 420 660 730 960 1020 1150 1150 1240 1350 1410 1430 1580 1660 1810 1830 1990 2210 | 41 101 231 351 851 971 1031 1041 1151 1201 1231 1331 1351 1401 1421 1501 1541 1681 1751 1811 1831 1841 1851 1961 1961 2071 2181 2201 | 72 332 402 422 542 572 652 652 952 1012 1242 1362 1392 1642 1852 1912 2022 2102 | 13 33 43 133 253 253 253 653 653 663 773 1023 1023 1443 1653 1813 1813 1973 | 4 114 174 174 1894 1024 1074 11774 1384 14574 14574 1824 1824 1824 1824 | 125 475 485 495 555 705 965 1125 1205 1275 1365 1275 1375 1745 1755 1915 1955 | 86 576 586 796 916 1016 1026 1256 1316 1316 1516 2556 2056 | 167 327 407 717 787 987 1187 1267 1297 1407 1447 1487 1587 1717 1817 1817 1847 2137 | 8 198 208 278 388 408 538 758 758 878 808 838 878 1058 1238 1248 1348 1348 1478 1636 1636 1636 1636 1636 1636 1636 163 | 19 29 69 169 279 499 659 709 737 779 809 909 1119 1329 1349 1439 1449 1609 2119 2189 |

Mitroglycerin (Liquid)

| Composition: | Molecular Weight: (C3H5H3OQ) 227 | | | | |
|---|--|--|--|--|--|
| С 15.9 H ₂ C — ОМО ₂ | Oxygen Belence: CO: % 3.5 CO % 24.5 | | | | |
| N 18.5 h ₂ c ONO ₂ | Density: gm/cc 25°C, Liquid 1.59; 20°C, Liquid 1.596 | | | | |
| 0 63.4 | Mobile Point: *C Labile form 2.2 Stable form .13.2 | | | | |
| C/H Ratio 0.109 | Freezing Point: *C | | | | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 15 | Belling Point: *C Decomposes 145 | | | | |
| Somple 14th 20 mg Picatinny Arsenal Apparatus, In. 1 1b wt 1 | Refrective Index, no. 1.4732 | | | | |
| Sample Wt, mg | 1.4713 | | | | |
| Friction Pandulum Tests | No | | | | |
| Steel Shoe | Vecuum Stability Test: cc/40 !1rs, at | | | | |
| Fiber Shoe | 90°C cc/gm/6 hrs 1.6 | | | | |
| BMs Bullet Images Tricks Tricks | - 100°C cc/gm/16 hrs 11+ | | | | |
| Riffe Bellet Impest Test: Trials | 120°C | | | | |
| % Explosions 100 | 135°C | | | | |
| Partials 0 | 150°C | | | | |
| Burned 0 | 200 Gram Bomb Saud Test: | | | | |
| Unaffected 0 | Sond, gm Liquid method 51.5 | | | | |
| Explosion Temperature: *C Seconds, 0.1 (no cop used) 1 5 Explodes 222 10 15 | Specitivity to initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl | | | | |
| 20 | Bellistis Morter, % THT: (a) 140 | | | | |
| | Tousial Teat, % Thif: (b) 181 | | | | |
| 75°: International fleet Test: 9: Loss in 48 Hrs | Plate Dank Test: Method | | | | |
| | Condition | | | | |
| 100° C Heat Test: | Confined | | | | |
| 160° □ Heut Test: 96 Loss, 1st 48 H/c 3. € | Continso | | | | |
| | Density, gm/cc | | | | |
| % Loss, 1st 48 H/c 3. € | | | | | |
| 96 Loss, 1st 48 H/c 3.€ 96 Loss, 2nd 48 Hrs 3.5 Exp osion in 160 Hrs None | Density, gm/cc Brisance, 16 TNT Detantiles Rate: Confinement Glass Steel | | | | |
| 96 Loss, 1st 48 H/c 3. € 96 Loss, 2nd 48 Hrs 3. 5 | Density, gm/cc Brisance, 16 TNT Detanstien Rate: | | | | |

Nitroglycerin (Liquid)

| Beester Scrattivity Test: Condition | | Decemposition Equation: Oxygen, atoms/sec | 1017-3 | 1019.2 |
|--|-----------------|--|---------------|--------------|
| Tetryl, gm | | (Z/sec) | | |
| Wax, in. for 50% Detonation | | Heat, kilocalorie/mole (ΔΗ, kcal/mol) | 41.4 | 45.0 |
| Wax, gm | | Temperature Ronge, °C | 90-135 | 125-150 |
| Density, gm/cc | | Phase | Liquid | Liquid |
| Neet of: | | Armer Plate Impact Test: | | |
| Combustion, cal/gm | 1616 | Arms Field Impect Text. | | |
| Explosion, cal/gm | 1600 | io mm Morter Projectile: | | |
| Gas Volume, cc/gm | 715 | 50% Inert, Velocity, ft. | /sec | |
| Formation, cal/gm 🎽 | 400 | Aluminum Fineness | | |
| Fusion, col/gm Detonation, cal/gm | 1486 | 500-lb General Purpose Se | embe: | |
| Specific Heat; co!/gm/*C | | | | |
| Liquid | 0.356 | Plate Thickness, inches | | |
| - | | 1 | | |
| Solid | 0.315 | 11/4 | | |
| • | | 11/4 | | |
| | | 13/ | | |
| Burning Rate: | | 1 174 | | |
| cm/sec | | Comb Drop Test: | | |
| Thermel Conductivity: cal/sec/cm/°C | | 17, 2000-16 Semi-Armor-l | Piercing Bemb | vs Concrete: |
| Coefficient of Expension: | | Max Safe Drop, ft | | |
| Linear, %/°C | | 500-15 General Purpose 8 | lemb vs Cencs | ate: |
| Volume, %/°C | | Height, ft | | |
| A4- A NA-4 | | Trials | | |
| Herdness, Mehs' Scele: | | Unaffected | | |
| Yanada Madahar | | Low Order | | |
| Young's Medulus: | | High Order | | |
| E', dynes/cm² | | | | |
| E, lb/inch ² Density, gm/cc | | 1001)-Ib General Purpose (| Bomb vs Conci | ele: |
| | | Height, ft | | |
| Compressive Strength: Ib/inch² | | Trials | | |
| | | Unoffected | | |
| Vapor Prossure: | | Low Order | | |
| °C mm Mercury °C | mm Mercury | High Order | | |
| | | | | |
| 20 0.00025 60 30 0.00083 70 | 0.0188 0.043 | | | |
| 40 0.0024 80 | 0.043 | | | |
| 50 0.0073 90 | 0.23 | 1 | | |

Nitroglycerin (Liquid)

AMCP 706-177

| Fragmentation Tref: | Shaped Charge Effectiveness, TNT = 100: |
|---|--|
| 90 mm HE, M71 Projectile, Let WC-91: Denziny, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hole Volume Hole Depth |
| Total No. of Fragments: For TNT | Coloriess Coloriess |
| For Subject HE , 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: Propellant ingredient, demolition explosive ingredient, grenade burster ingredient |
| Total No. of Fragments: For TNT For Subject HE | Method of Looding: |
| Fregment Velocity: ft/sec | Leading Density: gm/cc |
| At 9 ft At 251/ ₆ ft Density, gm/cc | Sterege: Method With acetone or other desensitizer. |
| Blast (Relative to TNT): | generally not stored Hazard Class (Quantity-Distance) Class 9 |
| Air: Peak Pressure Impulse Energy | Compatibility Group Excidation |
| Air, Confined: | Heat of Transition, cal/gm: Transition: |
| Under Weter: Peak Pressure Impulse | Liquid → labile 5.2 Labile → stable 28.0 Liquid → stable 33.2 |
| Energy | Hydrolysis, \$ Acid: 1.0 days at 22°C < 0.002 |
| Underground: Peak Pressure Impulse | 5 days at 60°C 0.005 |
| Energy | Minutes 10+ |
| | <u> </u> |
| | |

Mitroglycerin (Liquid)

Gas Evolved at Atmospheric Pressure, cc:

| Sample Wt, gm | | 1.6 |
|-------------------|-----|-----|
| Temperature, oc | 65 | 75 |
| Time, hours | 20 | 40 |
| Volume of gas, cc | nil | nil |

Viscosity: (c)

| °C | Centipoises |
|----------|-------------|
| 10 | 69.2 |
| 20 | 3€∙0 |
| 30 30 | 21.0 |
| | 13.6 |
| 50 60 | 9.4 |
| 60 | 6.8 |

Pregmentation Test:

20 mm HE, Mark 1, Projectile, Total No. of Fragments for:

Mitroglycerin 22 Tetranitromethane 17

Minimum Propagating Plameter: (d)

| Macthylphthalate | Min. Propagating Diameter, inches | Milure in inches |
|--|--------------------------------------|----------------------------------|
| 0 5 10 15 20 22.5 25 | (3/16 Cmirns) 1/3 1/4 3/4 1 1.55 | 1/8 1/8 3/16 2/8 7/7 |

Sensitivity to Electrostatic Machange, scales (test condition, unconfined; no value given for confinement); > 12.5

Solubility, grame of nitroglycerin/100 gm (\$) of:

| | ter | Al | cohol . | Trichler | rethylene | Carbon Teta | achloride |
|----------------|----------------------|-----------|--------------|----------|-----------|-------------|-----------|
| <u>°c</u> | Ź | <u>°с</u> | 2 | °C | 4 | °c | 2 |
| 15 20 50 | 0.16 0.18 0.25 | 50 0 | 37•5 54•0 | Roma | 22 | Rm | 2 |

Nitroglyceri : (Liquid)

| Carbon Dis | ulfide | gm/100 gm (d), at | 25°C in |
|------------|----------|-------------------|---------|
| °c | £ | Ether | 00 |
| Ambient | 1 | 2:1,Ether:Alcohol | > 100 |

Soluble in all Proportions in:

| Methanol | Phenol |
|-------------------------|------------------------------|
| Acetone | Pyridine |
| Ether | Xylene |
| Ethyl acetate | Nitrobenzene |
| Amyl acetate | p-Ni trotoluene |
| Methyl nitrate | Liquid DNT |
| Ethyl nitrate | Chloroform |
| Nitroglycol | Ethyl chloride |
| Tetrani trodigly cerine | Ethyl bromide |
| Acetic acid | Tetrachloroethylene |
| Benzene | Dichloroethylene |
| Toluene | Trimethyleneglycol Dinitrate |

Solubility in NG, of:

| Alc | ohol | Ī | NT | 7 | NT | Wa | ter |
|---------------|------------|----|----|-----------|----------|----|------|
| <u>ိင</u> | ž | °c | ž | <u>°C</u> | ½ | °c | 2 |
| 0 20 50 | 3.4 5.4 | 20 | ?5 | 20 | 30 | 25 | 0.06 |

Preparation:

Glycerine is usually nitrated at 25°C, or below, by adding it very slowly to a well agitated mixture of nitric and sulfuric acids, e.g., 40/59.5/0.5, nitric acid/sulfuric acid/water, using an acid/glycerine ratio of approximately 6. Agitation of the reaction mixture is accomplished by use of compressed air. A rapid temperature rise, or appearance of red fumes, automatically requires dumping of the charge, immediately, into a drowning vessel filled with water. After all the glycerine has been added to the nitrator, agitation and cooling are continued until the temperature drops to about 15°C, and the charge is then run into a separator where the NG rises to the top, and is run off to the neutralizer. The nitroglycerin is washed first with water, then with sodium carbonate, and finally with water. The resultant NG when washed with water, produces washings which do not color phenolphthalein, and itself is neutral to litmus paper.

Nitroglycerin (Liquid)

Origin

Nitroglycerin was first prepared in 1846 or 1847 by Ascanio Sobrero, an Italian chemist (Nem Acad Torino (2) 10, 195 (1847)). For several years after this discovery, nitroglycerin attracted little interest as an explosive until Alfred Nobel in 1864 patented improvements in its manufacture and method of initiation (British Patent 1813). Nobel gave the name dynamite to mixtures of nitroglycerin and bon-explosive absorbents, such as charcoal, siliceous earth or Kieselguhr (Dritish Patent 1345 (1867)) Later developments led to gelatine dynamices. ammonia dynamites, and so called straight dynamites. The first propellants using nitroglycerin were called Hallistite (Nobel, Eritish Patent 1471 (1888)) and Cordite (Fel and Dewar, British Patents 5614 and 11,664 (1889)).

Destruction by Chemical Decomposition:

Nitroglycemin is decomposed by adding it slowly to 10 times its weight of 18% sodium sulfide (Mags.9Hgo). Meat is liberated by this reaction; but this is not hazardous if stirring is maintained during the addition of nitroglycemin and continued until solution is complete.

References: 48

- (a) A. E. Blatt. Compilation of Data on Organic Explosives, OSRD Report No. 2014, 29 February 1044.
 - (b) Ph. Maoum, Z ges Schiess-Sprengstoffw, pp. 181, 239, 267 (27 June 1932).
 - (c) Inndolt Bornstein, Physikalisch-Chemische Tabellen, 5th Ed. (1923).

International Critical Tables.

B. T. Fedoroff et al, A Manual for Explosive Laboratories, Vol V-IV, Lefax Society, Inc., Philadelphia, 1943, 1946.

- (d) H. A. Strecker, Initiation, Propagation and Luminosity Studies of Liquid Explosives, OSRD Report No. 5509, 3 December 1945.
 - (e) Also see the following Picatinny Arsenal Technical Reports on Mitroglycerin:

| <u> </u> | <u>1</u> | 2 | 3 | 4 | 2 | <u>6</u> | 7 | <u>8</u> | 2 |
|---|--|--|--|---|------------------------------|--|--|---|---|
| 620 660 800 1020 1150 1210 1410 1620 1680 | 511 551 701 891 1031 1041 1151 1221 1611 1651 1731 1781 1851 1931 2021 2181 | 652 672 792 922 1142 1282 1362 1542 1662 1742 1752 1992 | 233 343 673 903 1023 1443 1663 1863 1993 | 454 1024 1074 1084 1454 1524 1624 1674 | 1155 1235 1955 2015 | 1206 1456 1496 1556 1616 1786 1816 1896 2056 | 817 837 1197 1297 1637 1817 1847 | 768 1348 1398 1738 1918 2098 | 69 249 579 709 1349 2119 |

⁴⁸See footnote 1, page 10.

2201

Nitroguanidine

| Competition: | | Melecular Weight: (CHI,NI,O2) | 104 |
|---|------------|--|--------------------|
| % c 11.5 NH ₂ | • | Oxygen Belence: CO ₂ % | -31 |
| н 3.9 ни— с | | CO % | -15.4 |
| и 53.8 | | Density: gm/c Crystal | 1.72 |
| n 30.8 | ! | Malting Paint: 'C | 2 32 |
| C/H Ratio 0.038 | | Freezing Point: *C | |
| Impact Sansitivity, 2 Kg Wt: | 1.0 | Boiling Point: *C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | 47 | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. | 26 7 | ng. | 1 |
| Sample Wt, mg | | n ₂₀ | |
| Friction Pendulum Test: | (e) | Vecuum Stubility Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Fibe: Shoe | Unaffected | 90°C | (a. 37 → |
| Riffe Bullet Impact Test: 5 Trials | (e) | 100°C | 6.44 |
| % | | 120°C | 0.44 |
| Explosions 0 | | 150°C | |
| Partials 0 | | 150 € | · |
| Burned 0 | | 200 Grem Bomb Scnd Test: | , |
| Unaffected 100 | | Sand, gm | 36.0 |
| Explosion Temperature: "C Seconds, 0.1 (no cap used) | | Sensitivity to Initiation: Minimum Detanating Charge | , gm |
| <u>.</u> | | Mercury Fulminate | |
| 5 Decomposes 275 | • | Lead Azide | 0.20 |
| 10 15 | | Tetryl | 0.10 |
| 20 | | Bellistic Morter, % TNT: (| 104 |
| | | Trauzi Test, % TNT: (| b) 101 |
| 75°C International Heat Test: % Loss in 48 Hrs | 0.04 | , | c) |
| | · | Method | Α . |
| 100°C Heat Test: | | Condition | Pressed |
| % Loss, 1st 48 Hrs | 0.18 | Confined | No |
| % Loss, 2nd 48 Hrs | C.09 | Density, gm/cc | 1 .50 95 |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| Flormability Index: | | - Detenation Rate: (4 | e) |
| Hygroscopicity: % 30°C, 90% RH | | — Condition | |
| пункасорияту: % 30°С, 90% RH | None | Charge Diameter, in. | |
| Voletility: | None | Density, çm/cc | 1.55 |
| · ···································· | HOHE | Rate, meters/second | 765 0 |

Nitroguanidine

| regmentation Test: | Shaped Charge Effectiveness, TNT = 100 | : |
|--|---|---------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cor | 105 |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Yotel No. of Fragments: | Color: (color) | |
| For TNT | Color1 | ess |
| For Subject HE | | |
| Stock MP AARSAS Section 11 - A MO P. | Principal Uses: | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | Propellant composition ingredi- bursting charge ingredient | ent, |
| Density, gm/cc | amenated emerge impression | |
| Charge Wt, Ib |] | |
| Total No. of Fragmests: | Method of Loading: | |
| For TNT | | |
| For Subject HE | | |
| | Leeding Density: gm/cc | |
| regment Velocity: ft/sec | At 3000 pmi | 0.95 |
| At 9 ft At 251/4 ft | Storage: | |
| Density, gm/cc | | |
| source and the second | Method | Dry |
| | | - |
| lest (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 |
| Alex | Compatibility Group | Group I |
| Peak Pressure | 1 | • |
| Impulse | Exudation | |
| Energy | | |
| Ale Coulines | Solubility, gm/100 gm (%), in: | |
| Alr, Confined: Impulse | °C | 0.44 |
| · · • | Water 25 | 9.0 |
| Under Weter: | 1.0 N Potassium | - |
| Peak Pressure | Hydroxide 25 40% Sulfuric Acid 0 | 1.2 3.4+ |
| linpulse | 25 | 8.0+ |
| Energy | * gm/100 cc solution | |
| Underground: | Booster Sensitivity Test: | (a) |
| Peuk Pressure | Condition Tetryl, gm | Pressed 100 |
| Impulse | Wax, in. for 50% Detonation | 0.67 |
| Energy | Density, gm/cc | 1.41 |
| | Heat of: | |
| | Combustion, cal/gm | 1995 |
| | Explosion, cal/gm Gas Volume, cc/gm | 7 <u>21</u> 1077 |
| | 1 USS YULUME, CC/AM | 1077 |

ころう かんこう

Preparation:

(Chemistry of Powder and Explosives, Davis)

Four hum, ed gms of dry guanidine nitrate is added in small portions to 500 cc concentrated sulfuric acid at 10°C, or below. As soon as all crystals have disappeared the milky solution is poured into 3 liters of ice-water, and allowed to stand until crystallization is complete. The product is filtered, rinsed with water, and recrystallized from about 4 liters of boiling water, yield about 90%.

Origin:

Mitroguanidine was first prepared in 1877 by Jousselin, but it was 1900 before it found use in propellant compositions. During World War I, nitroguanidine was used by the Germans as an ingredient of bursting charge explosives.

Destruction by Chemical Decomposition:

Mitroguanidine is decomposed by dissolving in 15 times its weight of 45% sulfuric acid at room temperature and warming the solution until gas is evolved. Hesting is continued for one-half hour.

References: 49

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Pa.t III Miscellaneous Sensitivity Tests; Performance Tests, OSRU Report No. 5746, 27 December 1945.
 - (b) Canadian Report, CE-12, 1 May-15 August 1941.
 - (c) D. P. MacDougall, Mathods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of ROX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) Pepartments of the Army and the Air Force TM 9-1910/TO 11A-1-34, Military Explosives, April 1955.

⁴⁹See footnote 1, page 10.

Mitroguenidine

(*) Also see the following Picatinny Arsenal Technical Reports on Mitroguanidine:

2 1 2 3 6 7 8 9
1490 1391 1282 1183 1336 907 758 1439
2181 1392 1423 2177 1749

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Nitroisobutylelycerol Trinitrate (NIBTN) Liquid

| Compositions | Melecular Weight: (ChRCNhO12) | 286 |
|--|--|-------------------------|
| % c 16.8 o _g No-cH ₂ | Oxygen Palence: CO ₂ % CO % | 0.0 |
| $\frac{19.6}{19.6}$ $\frac{0_2 \text{NO} - \text{CH}_2}{19.6}$ $\frac{19.6}{19.6}$ | Density: gm/cc 20°C | 1.64 |
| 0 61.5 02NO-CH2 | Melting Point: *C | |
| C/H Ratio 0.126 | Freezing Point: 'C | -39 |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, crn 25 | Boiling Point: *C | |
| Sureau of Mines Apparatus, crn 25 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | Refrective Index, np. np. np. np. np. | 1.4896 1.4874 |
| Friction Pundulum Test: Steel Shoe Fiber Shoe | Vecuum Stability Test: cc/40 Hrs, at 90°C | |
| Riffe Bullet Impact Test: Trials ** Explosions Partials | 120°C 135°C 150°C | |
| Burned Unaffected | 200 Green Bornh Send Test: Sond, gm 0,2 gm sample absorb | ed 26 |
| Explosion Temperature: °C Seconds, 0.1 (no cap used) 1 5 Ignites 185 10 15 | Secultivity to initiation: Minimum Detonating Charge, gm Marcury Fulminate Lead Azide Tetryi | |
| 20 | Ballistic Marter, 16 THT: | |
| | Treated Test, % THT: | |
| 75°C International Heat Test: 96 Loss in 48 Hrs | Place Dent Test: Method Condition | |
| 100°C Mont Test: % Loss, 1st 48 Hrs | Condition Confined | |
| % Loss, 2nd 48 Hrs | Density, gm/cc | |
| Explosion in 100 Hrs | Brisonce, % TNT | |
| Flammability Index: | Y . | nds (1 mm WEJ! |
| | Condition | Li q uid 0.39 |
| Hygrescopicity: % | Charge Diameter, in. Density, gm/cc | 1.64 |

Mitroisobutylglycerol Trinitrate (MIRTM) Liquid

| Fragmentation Test: | Shaped Charge Effectivence, THT = 100: |
|---|--|
| 98 sem HE, M71 Projectile, Let WC-91: Geneity, gm/cc Charge Wt, Ib Tatul No. of Fragments: For TN7 For Subject HE | Glass Cones Steel Cones Hole Volume Hole Depth |
| | Color: Yellow oil Principal Uses: Gelatinizing agent for |
| 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | ni trocellulose |
| Total No. of Fragments: For TNT For Subject HE | Method of Loading: |
| Renoment Value to te tear | Leading Density: gm/cc |
| Fregment Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc | Storage: Method Liquid |
| Blast (Relative to TPCT): | Hazard Class (Quantity-Distance) |
| Air: Peok Pressure Impulse Energy | Compatibility Group Exudation |
| Air, Confined: Impulse Under Weter: | Solubility: Soluble in metayl and ethyl alconols, acetone, ether, ethylenedichloride, chloroform and benzene. |
| Peak Pressure Impulse Energy | Insoluble in mater carpon Aigulphide, and petroleum ether. Toxicity: |
| Underground: Prock Pressure Impulse Energy | Slight, decidedly less 200 nitroglycerin. Gelatini ing Action: Slight on nitrocellulose. 82.2°C KI Test; Mir.tes 2 |
| | |

Nitroisobutylglycerol Trinitrate (NIBTN) Liquid

Preparation:

A total of 675 gm 37% formalin is added to 150 gm nitromethane containing 2 gm potassium carbonate hami-hydrate. The first 200 gm formalin is added slowly, keeping the temperature below 30°C, and then the heat of reaction is allowed to raise the temperature to 60°C, and the mixture then heated two hours at 90°C. The reaction mixture is then concentrated at reduced year we and diluted, and this process repeated several times to remove formaldehyde. After the linal concentration the cooled mixture is filtered and the crystalline product recrystallised from alcohol and then several times from ether and dried.

The nitrated product is then obtained by nitrating 50 gm nitroisobutylglycerol with 300 gm mixed acid (60/36/2, sulfuric acid/nitric acid/water) below 15°C for 1.5 hours.

Origin:

This explosive (also called Trimethylolnitromethane Trinitrate, Mitroisobutanetriol Trinitrate, Mitroisobutylglycerin Trinitrate and incorrectly but widely used Mitroisobutylglycerol Trinitrate) was first described in 1912 by Hofwimmer (Z ges Schiess - Sprengstoffw 7, 43 (1912). Hofwimmer prepared the compound by the condensation of 3 moles of formaldehyde with 1 mole of nitromethane in the presence of potassium bicarbonate, the subsequent nitration of the product. The explosive can now be produced from coke, air, and natural gas.

References: 50

- (a) H. A. Amronson, Study of Emplosive's Derived from Nitroperaffins, PATR No. 1125, 24 October 1941.
 - (b) M. Aubry, Men poudr, 25, 197-204 (1932-33); CA 27, 4083 (1933).
 - (c) A. Stettbacher, Witrocellulose 5, 159-62, 181-4, 203-6 (1934); CA 29, 1250 (1935).
 - (d) W. de C. Crater, U.S. Patent 2,112,749 (March 1938); CA 32, 3964 (1938).
- (e) H. J. Hibshman, E. H. Pierson, and H. B. Haas, Ind Eng Chem 32, 427-9 (1940); (A 34, 3235 (1940).
 - (f) A. Stettbacher, Z ges Schiess Sprengstoffv 37, 62-4 (1942); (A 38, 255 (1944).

⁵⁰See footnote 1, page 10.

| Composition: | | Molecular Weight: | 32 5 | |
|---|---------------|-------------------------------|--------------|---|
| % Nitrosterch (12.50% N) | 49 | Oxygen Solonce: | | • |
| Barium Nitrate | 40 | CO ₂ % | -19 | |
| Mononi tronsph thalene | 7 | CO % | 8 | |
| Paranitroaniline | 3 | Density: gm/cc | | |
| 011 | 1 | Melting Point: *C | | |
| C/H Ratio | | Freezing Point: 'C | | |
| Impact Southfulty, 2 Kg Wt: | | Boiling Point: 'C | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | .51 | Refrective Index, no | | |
| Picatinny Arsenal Apparatus, in. | 8 | _ | | |
| Sample Wt, mg | | n _B | | |
| | | n ₂ | | |
| Friction Pendulum Test: | | Vacuum Stebility Test: | | |
| Steel Shoe Crackle | es, snaps | cc/40 Hrs, at | | |
| Fiber Shoe Unaffe | e te d | 50°C | | |
| Rifle Bellet Impact Test: 10 Triols | 8 Triels* | 100°C | 11+ | |
| • | | 120°C | | |
| Explosions 97 | % 0 | 135°C | | |
| Partials 0 | 13 | 150°C | | |
| Burned 0 | 0 | 200 Gram Bomb Send Test: | | |
| Unoffected 10 *Packed in paper | 87 | Sand, gm | 3 9•5 | |
| Explosion Terreporuture: °C | | Sensitivity to Initiation: | | - |
| Seconds, 0.1 (no cop used) | | Minimum Detonating Charge, gm | | |
| 1 | | Mercury Fulminate | 0.26 | |
| 5 Decomposes 195 | | Lead Azide | | |
| 16 | | Tetryl | | |
| 15 20 | | Ballistic Morter, % TNT: (a) | 96 | • |
| | | Trouzi Test, % TNT: | | _ |
| 75°C International Heat Test: % Loss in 48 Hrs | 0.2 | Method | | |
| 100°C Heet Test: | | Condition | | |
| % Loss, 1st 48 Hrs | 0.3 | Confined | | |
| % Loss, 2nd 48 Hrs | 0.3 | Density, gm/cc | | |
| Explosion in 100 Hrs | None | Brisance, % TNT | | |
| Flemmebility Index: | · | Detenation Rate: Confinement | | |
| | | Condition | | |
| Hygrescopicity: % 30°C, 90% RH | 2.1 | Charge Diameter, in | | - |
| | | Density, gm/cc | | |
| Volatility: | | | | |

Nitrostarch Demolition Explosive (NSX)

| Fragmentation Test: | Shoped Charge Effectiveness, Th | rr = 100: |
|--|---------------------------------|-------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Gloss Cones | Steel Cones |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | Color: | |
| For TNT | | |
| For Subject HE | Principal Uses: Demolition, | bursting charges, |
| 3 iach HE, M42A1 Projectile, Let KC-5: | and priming | |
| Density, gm/cc | 1 | |
| Charge Wt, Ib | | |
| Charge Wi, ib | | |
| Total No. of Fragmonts: | Method of Looding: | Hand tamped |
| For TNT | | |
| For Subject HE | | |
| | Leading Density: gm/cc | |
| Fregment Velocity: ft/sec | Apparent | 0.92 |
| At 9 ft At 25½ ft | Sterege: | |
| Density, gm/cc | | |
| Density, gm/cc | Method | Dry |
| Blast (Relative to TNT): | Hazard Class (Quantity-Distor | nce) Class 9 |
| Air: | Compatibility Group | Group I |
| Peak Pressure | | |
| Impulse | Exurtation | None |
| Energy | | |
| Air, Confined: | 120°C Heat Test: | |
| Impulse | 0-1 64-1 | Minutes |
| AA A SAA | Salmon Pink Red Fumes | 70 255 |
| Under Weter: Peak Pressure | Explodes | 2 56 |
| Impulse | <u>-</u> | |
| Energy | | |
| Undergreund: Peak Pressure | | |
| impulse | | |
| Energy | | |
| | | |
| | | - |
| | | |
| | | |

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Nitrostarch Pemolition Explosive (NSX)

Freparation: (b)

The nitration of starch proceeds with the formation of hexanitro starch according to the following equation:

 $2C_6H_{10}O_5 + 6HMO_3 \rightarrow C_{12}H_{11}O_4(OMO_2)_6 + 6H_2O$

Tapioca starch is considered the best for nitration purposes, although other starches give inirly stable products. The starch, pretreated to remove pils, fats and water soluble impurities, is dried and acreened. Feeding of the dried starch into stainless steel nitrators containing mixed acid (62%-63% HNO₂ and 37%-39% H₂SO₃) is done clowly with constant agitation of the mixture. The heat evolved must be controlled by cooling coils. The nitrated starch is separated from the spent acid, washed with a large amount of water and centrifuged. Final drying is on trays heated to 35°-40°C with air. This product is so sensitive even a static discharge might cause explosion.

Hitrostarch demolition explosives contain a high percentage of nitrostarch, an oxidizing agent, mineral oil, a stabilizer and/or other ingredients.

Origin:

Ritrostarch was first prepared in 1833 by Branconnot, who called it xyloidine (Ann chim phys [2] 52, 290 (1833)). T. J. Pelouse studied xyloidine further and reported its explosive properties (Compt rend 7, 713 (1836). It found military use in the United States during World Wars I and II as blasting explosives and as an ingredient of bursting charges and priming compositions.

References: 51

- (a) W. R. Tomlinson, Jr., Physical and Explosive Properties of Military Explosives, PATR No. 1372, 29 November 1943.
- (b) G. D. Clift and B. T. Fedoroff, A Manual for Explosives Laboratories, Vol I, Lefax Society, Inc., Philadelphia (1942).
 - (c) Also see the following Picatinny Arsenal Technical Reports on Mitrostarch Explosives:

| 1 | 2 | <u>4</u> | I | <u>8</u> | 2 |
|------|-------------|----------|------|--------------------|---------------|
| 1611 | 782 2032 | 1034 | 1117 | 8 38 848 | 1 2 69 |

⁵¹See footnote 1, page 10.

Octol, 70/30

| Composition: | | Melecular Weight: | 265 |
|---|------------|-------------------------------|---------------|
| % HNX | 70 | Oxygen Belence: | |
| DIA. | • - | CO, % CO % | -38 -7.5 |
| TMT | 30 | | |
| | | Benefity: gm/cc Chat | 1.80 |
| | | Molting Point: *C | |
| C/H Ratio | | Freezing Point: "C | |
| impact Sensitivity, 2 Kg Wt: | | Boiling Point: *C | |
| Bureou of Mines Apparatus, cm Sample Wt 20 mg | | Refrective Index, nº | |
| P catinny Arsenal Apparatus, in. | 18 | n <u>e</u> | |
| Sample Wt, mg | 26 | n _p | |
| Frietien Pendulum Test: | | Vocuum Stability Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Filter Shoe | Unaffected | 90°C | |
| Rifle Sullet Impact Test: Trials | | 100°C | |
| % | | 120°C | 0.37 |
| Explosions 70 | | 135°C | |
| Partials | | 150°C | |
| Burned | | 200 Grem Bomb Sand Test: | _ |
| Unaffected | | Sond, gm Emploratory | 58.4 |
| Explosion Temperature: | °C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, gm | |
| l 5 Flames erratically | 335 | Mercury Fulminata | |
| 10 | | Lead Azide | 0.30 |
| 15 | | Tetryi | |
| 20 | | Ballietic Morter, % TNT: | 115 |
| SEA Commenter of Maria Park | | Treuzi Test, % TNT: | |
| 75 C International Heat Tust: % Loss in 48 Hrs | | Plate Dent Test: Method | |
| | | Condition | |
| 100°C Heat Tent: | • | Confined | |
| % Loss, 1st 48 Hrs | | Density, gm/cc | |
| % Loss, 2nd 48 Hrs Explosion in 100 Hrs | | Brisance, % TNT | |
| | | Detenation Rate: | |
| Flommobility Index: | | Confinement | None |
| | | Condition | Cast |
| Hygrescopicity: % | | Charge Diameter, in. | 1.0 |
| Volatility: | | Density, gm/cc | 1.80 |
| | | Rate, meters/second | 8 37 7 |

Octol, 70/30

| Seaster Sensitivity Test: Condition | , | Decomposition Equation: Oxygen, groms/sec |
|-------------------------------------|--------------|---|
| Tetryi, om | • | (Z/sec) |
| Wax, in. for 50% Detonation | | Heat, kilocalorie/mole |
| · · · · · | | (ΔH, kcal/mol) |
| Wax, gm | | Temperature Range, °C |
| Density, gm/cc | | Phose |
| Heat of: | 2722 | Armer Plate Impect Test: |
| Combustion, cal/gm | 1074 | |
| Explosion, car/gm | • | 60 mm Marter Projectile: |
| Gas Volume, cc/gm | 847 | 50% Inert, Velocity, ft/sec |
| Formation, cal/gm | | Aluminum Fineness |
| Fusion, cal/gm | | 500-lb General Purpose Bomhs: |
| Specific Heet: c * /gm/°C | | |
| appenies susse; C (right) C | | Plate Thickness, inches |
| | | 1 |
| | | 162 |
| | | 11/4 |
| | | 154 |
| Surning Rate: | | |
| cm/sec | | Somb Drop Test: |
| Thermal Conductivity: | | - John Drop Test; |
| cal/sec/cm/°C | | T7, 2000-lb Semi-Armos-Piercing Bomb vs Concrete: |
| Coefficient of Expension: | | Max Safe Drop, ft |
| Linear, %/°C | | 500-th General Purpose Bomb vs Concrete: |
| Volume, %/*C | | Height, ft |
| | | Trials |
| Hardness, Mahs' Scale: | | Unoffected |
| | | Low Order |
| Young's Modulus: | | High Order |
| E', dynes/cm² | | |
| E, ib/inch² | | 1000-lb General Purpose Bomb vs Concrete: |
| Density, gm/cc | | |
| Commence Street A. th. 17-1-17 | 1510 | Height, ft |
| Compressive Strength: Ib/inch² | See below | Trials |
| | | Unaffected |
| Vapor Pressure: | | Low Order |
| *C mm Mercury | | High Order |
| Compressive Strength: 1b/inch2 | * | |
| Average (10 tests) | 1510 | Ultimate Deformation: % |
| High Low | 1740 1330 | Average (10 tests) 2.26 |
| - | - J.J. | High 2.58 Low 1.97 |

^{*}Test specimen 1/2" x 1/2' cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

Octol, 70/30

| Fragmentation Test: | Shoped Charge Effectiveness, TNT == 100: | |
|---|---|----------------------|
| (#) man HE, M71 Projectilis, Let WC-91; Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hole Volume Hole Dcpth | |
| Total No. of Fragments: For TNT | Color: | Buff |
| For Subject HE 3 lack ME, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: HE projectile and bomb | filler |
| Total No. of Fragmonds: For TNT For Subject HE | Method of Loading: | Cast |
| Fregment Velocity: 11/sec At 9 ft At 2514 ft | Looding Density: gm/cc Storage: | 1.80 |
| Density, gm/cc | Method | Dry |
| Blant (Relative to TNT): | Hazarri Class (Quantity-Distance) | class 9 |
| Air: Peak Pressure Impulse Energy | Compatibility Group Exudation | Group I |
| Air, Confined: Imputse Under Weter: Peak Pressure Imputse Energy | Work to Produce Rupture: ft-lb/inch ³ Average (10 tests) High Low Efflux Viscosity, Saybolt Seconds: | * 1.55 1.87 1.10 5 9 |
| Underground: Peak Pressure Impulse Energy | *Test specimen 1/2" x 1/2" cylinder (s mately 3 gm) pressed at 3 tons (6,000 total load or 30,000 psi with a 2 min time of dwell. |) 1b) |

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Octol, 70/30

Effect of Altitude. Charge Diameter and Degree of Confinement on Detonation Velocity* (Reference b)

| , | | | h Column | | h Column |
|---------------------|---------------------|----------|----------------------|----------|------------|
| Explcaive | Simulated Altitude, | Confined | Unconfined | Confined | Unconfined |
| | Feet | m/s | m/8 | m/s | E/8 |
| 70/30, RDX/TNT; | Ground | 7900 | 8100 | 7660 | 8030 |
| density, gm/cc 1.62 | 30,000 | 8020 | 8120 | 7900(4) | 7800 |
| | 60,000 | 8040 | 8140 | 8010 | 7950 |
| | 90,000 | 8060 | 7980 | 8010 | 7710 |
| Average | | 8005 | 8085 | 7895 | 7873 |
| 70/30, HMX/TNT; | Ground | 7960 | 7900(4) | 7870 | 7640(4) |
| density, gm/cc 1.61 | 30,000 | 8050 | 8060 | 7930 | 7710 |
| | 60,000 | 8020 | 7 9 30 | 7890 | 7650 |
| | 90,000 | 7950 | 8000 | 7940 | 7650 |
| Average | : | 7995 | 7973 | 7908 | 7663 |

^{*70/30} Octol confined charge in 1/4" steel tube, AISI 1015 seamless, 1" diameter 18" long, and 2" diameter 7" long. All means were determined from sets of five values unless otherwise indicated by (). A 26 gm tetry booster was used to initiate each charge.

Average Pragment Velocities at Various Altitudes* (g)

| | | Simulated Altitude, Feet | | | et |
|----------------|------------------|--------------------------|--------|-------------|--------|
| Explosive | Charge Diameter, | Ground | 30,000 | 60,000 | 90,000 |
| | Inches | m/s | | B √8 | |
| 70/30, RDX/TNT | 1 | 3415 | 3672 | 3666 | 3685 |
| | 2 | 4647 | 5192 | 523€ | 6011 |
| 70/30, HMX/TMT | 1 | 3366 | 3680 | 4014 | 3617 |
| | 2 | 4703 | 5464 | 6089 | 6111 |

^{*}Outside diameter 2.54"; inside diameter 2.04"; length 7".

CONTRACTOR OF THE SECOND

Octol, 70/30

Tensile Strength:*

| | lb/inch2 |
|-------------------|----------|
| Average (8 tests) | 169 |
| High | 204 |
| Low | 128 |

*Test specimen as per Picatinny Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

| | lb/inch ² |
|--------------------|--------------------------------|
| Average (10 tests) | 1b/inch ² 73,200 |
| High | 79,300 |
| Low | 63,oc |

*Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 ps; with a 2 minute time of dwell.

Setback Sensitivity Test: ()

| Critical Pressure | 92,000 psi* |
|-------------------|-------------|
| Density, pm/cc | 1.72 |

*Pressure below which no initiation is obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

105 mm MR HE Projectile:

| Weight Group, grains | No. of Fragments |
|----------------------|------------------|
| 1/2 - 2 | 1297 |
| 2 - 5 | 665 |
| 5 - 10 | 1.97 |
| 10 - 25 | 661 |
| 25 - 50 | 471 |
| 50 - 75 | 247 |
| 75 - 150 | 322 |
| 150 - 750 | 295 |
| 750 - 2500 | 12 |
| Total Number | 4+67 |

| Composition; 96 | | Melecular Weight: | 276 |
|---|------------|--|--------------------------|
| 70 180X | 75 | Oxygen Belence: | |
| , | 17 | CO ₂ % | - 235 -€.3 |
| TNT | 25 | CO % | -5 · 3 |
| | | Density: gm/cc Caz 1 | 1.81 |
| | | Malting Point: °C | |
| C/H Ratio | | Freezing Point: "C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | | Beiling Point: *C | |
| Sample Wt 20 mg | | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. Sample Wi, mg | 17 25 | n _m | |
| Sumple Wi, mg | | n ₃₀ | |
| Fristian Pandulum Test: | | Vecuum Stability Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Fiber Shoe | Unsifected | 90.C | |
| 2iffe Sullet Impact Test: 10Trials 5 | · | — 100•C | |
| 3/16" Steel | 1/8" Al | 150.C | 0.39 |
| Explosions 70 | 70 | 135°C | |
| Portiols | | 150°C | |
| Burned | | 200 Grem Bomb Send Test: | |
| Unaffected 30 | 30 | Sond, om Exploratory | 62.1 |
| | | | |
| Explosion Temperature: | | Scalitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, gm Mercury Fulminate | |
| 5 Flames erratically | 7 350 | | |
| 10 | 3,70 | Lead Azide | 0.30 |
| 13 | | Tetryl | |
| 20 | | Bellistic Morter, % TNT: | 116 |
| | | Trouxi Teet, % TNT: | |
| 75°C International Heat Test: 96 Loss in 48 Hrs | | Plate Dent Test: Method | |
| 160°C Heat Test: | | Condition | |
| % Loss, 1st 48 Hrs | | Confined | |
| % Loss, 1st 46 Hrs | | Density, gm/cc | |
| Explosion in 100 Hrs | | Brisance, % TNT | |
| | | - Detenation Rate: | |
| Flommobility Index: | | Confinement | None |
| | | - Condition | Cast |
| Hygrasospicity: % | | Charge Diameter, in. | 1.0 |
| | | Density, gm/cc | 1.81 |
| Volatility: | | Rate, meters/second | 8643 |

| | | T | |
|--|--------------|-----------------------------------|------------------|
| Booster Sensitivity Test: Condition | | Decemposition Equation: | |
| _ | | Oxygen, atoms/sec (Z/sec) | |
| Tetryl, gm | | Heat, kilocalorie/mole | |
| Wax, in. for 50% Detonation | | (ΔH, kcal/mol) | |
| Wax, gm | | Temperature Range, *C | |
| Density, gm/cc | | Phase | |
| Heat of: | | Armor Plate Impact Test: | |
| Combustion, cal/gm | 267 6 | Armor France (impact) text: | |
| Explosion, cal/gm | 1131 | 60 mm Morter Projectile: | |
| Gas Valume, cc/gm | 830 | 50% Inert, Velocity, ft/sec | |
| Formation, cal/gm | | Aluminum Fineness | |
| Fusion, cal/gm | 29.4* | | |
| *Calculated for 76.9% HMX, 23.1 | | 500-lb General Purpose Samba: | |
| Specific Heat: cal/gm/°C -79°C | ** | Olata Thistones inches | |
| -80° to +80°C | 0.200 | Plate Thickness, inches | |
| -80° to +80°c 33° to 74°c | 0.245 | | |
| 90° to 150°C | 0.323 | 1 | |
| **Determined for 76.9% HMX, 23. | 1% TNT. | 11/4 | |
| | | 11/2 | |
| | | 1% | |
| Burning Rate: | | | |
| cm/sec | | Somb Drop Test: | |
| Thermal Conductivity: | |] | |
| ca:/sec/cm/°C | | 77, 2000-lb Sami-Armer-Piercing 9 | emb vs Concrete: |
| B-All-t-A-A-B | | Max Safe Drop, ft | |
| Coefficient of Expension: Linear, %/°C | | | |
| E11801, 30, C | | 500-lb General Purpose Bamb vs C | ionerota: |
| Volume, %/°C | | Height, ft | |
| | | Trials | |
| Hardness, Mahs' Scale: | | Unoffected | |
| | | Low Order | |
| Young's Modulus: | | High Order | |
| E', dynes/cm² | | | |
| E, lb/inch ² | | 1000-th General Purpose Bomb vs C | encrate: |
| Density, gm/cc | | | |
| Company Strength: It (Inch!) | 1340 | Height, ft | |
| Compressive Strength: Ib/inch ² | See below | Trials | |
| | | Unaffected | |
| Vapor Pressure: | | Low Order | |
| °C mm Mercury | | High Order | |
| Compressive Strength: 1b/inch2 | *** | | |
| | 1340 | Ultimate Deformation: % | |
| Average (10 tests) | 1340 | | |
| Average (10 tests) High Low | 1560 1040 | Average (10 tests) | 2.43 2.69 |

***Test specimen 1/2" x 1/2" cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total load or 30,000 psi with a 2 minute time of dwell.

| ragmentation Test: | Shaped Charge Effectiveness, TNT = 109: | | | | |
|--|--|-------------------|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Canes Steel Cane | 15 | | | |
| Density, gm/cc | Hole Volume | | | | |
| Chorge Wt, Ib | Hole Deptin | | | | |
| Total No. of Fragments: | Color: | Buff | | | |
| For TNT | | 2-2-2 | | | |
| For Subject HE | Frincipal Uses: HE projectile and bomb filler | | | | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | | | | |
| Density, gm/cc | | | | | |
| Charge Wt, Ib | • | | | | |
| Total No. of Fragments: | Method of Looding: | Cast | | | |
| For TNT | | | | | |
| For Subject HE | Leading Density: gm/cc | 1.81 | | | |
| agment Valualty: ft/sec | | 1.01 | | | |
| At 9 ft | 2 | | | | |
| At 251/2 ft | Sterage: | | | | |
| Density, gm/cc | Method | Dry | | | |
| est (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 | | | |
| Ale: | Compatibility Group | Group I | | | |
| Peak Pressure | | | | | |
| Impulse | Exudation | | | | |
| Energy | | | | | |
| Alr. Confined: | Work to Produce Rupture: ft-lb/in | ch ³ * | | | |
| Impulse | Average (10 tests) | 1.31 | | | |
| | High | 1.57 | | | |
| Under Water: Peak Pressure | Low | 1.07 | | | |
| Impulse | Efflux Viscosity, Saybolt Seconds | : 9.0 | | | |
| Energy | | | | | |
| Underground: | 1 | | | | |
| Peak Pressure | l | | | | |
| Impulse | } | | | | |
| Energy | | | | | |
| | *Test specimen 1/2" x 1/2" cylinde mately 3 gm) pressed at 3 tons (6 total load or 30,000 psi with a 2 time of dwell. | ,000 lb) | | | |

Frequent Velocity Test: M26 Hand Grenade:

(e)

| Explosive | Average Fragment Velocity, ft/sec over lat 5 feet | | | | | |
|----------------|--|--|--|--|--|--|
| Composition B | 515# | | | | | |
| 75/25 Cycletol | 4008 | | | | | |
| 75/25 Octol | #0#8 | | | | | |

| | lb/inch ² |
|-------------------------|----------------------|
| Average (10 tests) High | 266 330 |
| LOW | 226 |

*Test specimen as per Picatinuy Arsenal sketch XL-076B, at 21°C.

Modulus of Elasticity:*

| | lb/inch2 |
|--------------------|----------|
| Average (10 tests) | 62,100 |
| High | 75,900 |
| LOW | 45,200 i |

*Test specimen $1/2^n \times 1/2^n$ cylinder (approximately 3 gm) pressed at 3 tons (6,000 lb) total l(3d or 30,000 psi with a 2 minute time of dwell.

Setback Sensitivity Tele: (a)

Critical Pressure 176,000 pai*
Tomaity, ga/cc 1.80

*Frescrive below which no initiation 10 obtained and above which an increasing percentage of initiations can be expected as the setback pressure increases.

Pit Fragmentation Test:

(a)

105 mm M1 HE Projectile:

| Weight Group, grains | No. of Fragments |
|----------------------|------------------|
| 1/2 - 2 | 1611 |
| 2 - 5 | 777 |
| 5 - 10 | 535 |
| 10 - 25 | 719 |
| 25 - 50 | 480 |
| 50 - 75 | 246 |
| 75 - 150 | 339 |
| 150 - 750 | 293 |
| 75C - 2500 | . 8 |
| Total Number | 5008 |

Octol, 70/30; Octol, 75/25

Preparation:

Water-wet HRK is added slowly to molten TNT in a steam-jacketed kettle at a temperature of 100°C. The mixture is heated and stirred until all moisture is evaporated. The composition is cooled to a satisfactory pouring temperature and cast directly into ammunition components or prepared in the form of chips to be stored for later use.

References: 52

- (a) 1st Indorsement from Chief, Explosives Development Section, to Chief, Explosives Research Section, Picatinny Arsenal, dated 12 May 1958. Subject: "Properties of Octols and HTA-3."
- (b) A. W. O'Brien, Jr., C. W. Plummer, R. P. Woodburn and V. Philipchuk, <u>Detonation Velocity Determinations and Fragment Velocity Determinations of Veried Explosive Systems and Conditions</u>, <u>Mational Northern Corporation Final Summary Report NNC-F-13</u>, February 1958 (Contract DAI-19-020-501-ORD-(P)-58).

⁵²See footnote 1, page 10.

PB-RDX

| Sempositica: | | Molecular Weight: | 245 |
|---|-------------------|---|-------------|
| RDX | 90 | Oxygen Selence: | |
| | _ | CO. % | -62 |
| Polystyrene (unmodified) | 8.5 | CO % | -18 |
| Dioctylphthalate | 1.5 | Despity: gm/cc Unpressed Pellet pressed at 30,000 psi Melling Point: *C | 0.81 |
| C/H Ratio | | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | Unpressed 28 | Boiling Point: "C | |
| Somple Wt 20 mg | | Rofrective Index, no | |
| Picatinny Arsenal Apparatus, in | | n _{ss} | |
| Sample Wt, mg | 20 | n _s | |
| Friction Pondulum Test: | | | |
| Steel Shoe | Unaffected | Vocuum Stability Test: cc/40 Hrs, at | |
| Fiber Shoe | Unaffected | 90°C | •••• |
| | | - 100°C | |
| Rifle Bullet Impact Test: 10 Trials | , * | 120°C | 0.41 |
| Explosions 10 | | 135°C | |
| Partials 90 | | 150°C | |
| Burned 0 | | | |
| Unaffected 0 | | 200 Grem Bemb Send Test: Sond, gm | |
| Explesion Temperature: *(| | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 Smokes 21 | 75 | Lead Azide | |
| 10 | | Tetryl | |
| 15 | | | |
| 20 | | Ballistic Morter, % TNT: | |
| 2210 to a contract to a 22 | | Treusi Test, % TNT: | |
| 75 °C International Heat Test: % Loss in 48 11rs | | Plate Sent Test: Method | |
| 100°C Heat Test: | | Condition | • . |
| % Loss, 1st 48 Hrs | 0.00 | Confined | |
| % Loss, 2nd 48 Hrs | 0.00 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| Flow-nobility Indon | | Detenation Rate: | |
| Flammability Index: | | Confine nent | |
| Hygroscopicity: % | | Condition | |
| | | Charge Diameter, in. | |
| * Test procedure described | in PATR No. 2247, | Density, gm/cc | |
| May 1956. | | Rate, meters/second | |

| Beaster Sensitivity Test: Condition | Decomposition Equation: Oxygen, atoms/sec |
|---|---|
| Tetryl, gm | (Z/sec) |
| Wax, in. for 50% Detonation | Heat, kilocolorie/mole |
| Wax, gm | (ΔH, kcal/mol) Temperature Range, °C |
| Density, gm/cc | Phase |
| | |
| Heat of: Combustion, col/gm 302 | Armor Plate Impact Test: |
| Explosion, cal/gm 98 | • |
| Gas Volume, cc/gm | 60 mm Mortar Projectile: |
| Formation, cal/gm | 50% Inert, Velocity, ft/sec |
| Fusion, cal/gm | Aluminum Fineness |
| | 500-lb Ganerai Purposo Bombs: |
| Specific Heet: cal/gm/°C | Dieta Thickness to the |
| | Plate Thickness, inches |
| | 1 |
| | 11/4 |
| | 11/2 |
| | 154 |
| Barning Rate: | |
| cm/sec | Bomb Drop Text: |
| Thermal Conductivity: | |
| col/sec/cm/°C | 17, 2000-16 Semi-Armor-Piercing Bomb vs Concrete: |
| Confficient of Expension: | Max Safe Drop, ft |
| Linear, %/°C | ROO C. Command Dayman Day 1 |
| , | 500-i3 General Purpose Remb vs Concrete: |
| Volume, %/°C | Height, fr |
| Mandage Adabat Santa | Trials |
| Hardness, Mahs' Scale: | Unaffected |
| Young's Modulus: See below | Low Order |
| E', dynes, cm² | High Order |
| E, lb/inch ² | |
| Density, gm/cc | 1000-lb General Purpose Bomb vs Concrete: |
| | Height, ft |
| Compressive Strongth: Ib/inch ² 2403 211 | +9 Trials |
| Percent 8.9 13. | -1 Unaffected |
| Vapor Pressure: | Low Order |
| *C mm Mercury | High Order |
| Young's Modulus: * (a) Temperatur | 1 |
| Ambient 95 | <u> </u> |
| | 831 |
| Density, gm/cc 1.60 1. | .57 |

^{*}Pellets (Lot OAC-596-55) 0.750 inch diameter by 0.750 inch long, pressed at 30,000 ps: with 30-second dwell.

| Acthod of Load acting Density 0 10 10 10-19 Acroge: Method Hazard Class Compatibility | High wechanics explosive ling: 20 30 1.59 1.62 | Pressed , psi x 10 ³ Dry Class 9 | | |
|--|--|--|--|--|
| Hole Depth Color: Inincipal Uses: Author of Load aciding Density 0 10 10 10 10 Horage: Method Hazard Class Compatibility | High Eachanica explosive ling: 20 30 1.59 1.62 | Pressed , psi x 10 ³ Dry Class 9 | | |
| Author of Load acting Density 0 10 -10 1.49 terage: Method Hazard Class Compatibility | emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62 | Pressed , psi x 10 ³ Dry Class 9 | | |
| Acthod of Load aciding Density 0 10 1.49 Norage: Method Hazard Class Compatibility | emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62 | Pressed , psi x 10 ³ Dry Class 9 | | |
| Acthod of Load aciding Density 0 10 1.49 Norage: Method Hazard Class Compatibility | emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62 | Pressed , psi x 10 ³ Dry Class 9 | | |
| Acthod of Load acting Density 0 10 10 10-19 Acroge: Method Hazard Class Compatibility | emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62 | Pressed , psi x 10 ³ Dry Class 9 | | |
| Acthod of Load acting Density 0 10 10 10-19 Acroge: Method Hazard Class Compatibility | emplosive ling: r: gm/cc Pressed 20 30 1.59 1.62 | Pressed , psi x 10 ³ Dry Class 9 | | |
| needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility | e: gm/cc Pressed 20 30 1.59 1.62 | l, psi x 10 ³ Pry Class 9 | | |
| needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility | e: gm/cc Pressed 20 30 1.59 1.62 | l, psi x 10 ³ Pry Class 9 | | |
| needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility | e: gm/cc Pressed 20 30 1.59 1.62 | l, psi x 10 ³ Pry Class 9 | | |
| needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility | e: gm/cc Pressed 20 30 1.59 1.62 | l, psi x 10 ³ Pry Class 9 | | |
| needing Dentity 0 10 10 10 1,49 Norage: Method Hazard Class Compatibility | e: gm/cc Pressed 20 30 1.59 1.62 | l, psi x 10 ³ Pry Class 9 | | |
| 0 10 10 1,49 Norege: Method Hazard Class Compatibility | 20 30 1.59 1.62 (Quantity-Distance) | Dry Class 9 | | |
| 0 10 10 1,49 Norege: Method Hazard Class Compatibility | 20 30 1.59 1.62 (Quantity-Distance) | Dry Class 9 | | |
| 10 1.49 Norege: Method Hazard Class Compatibility | 1.59 1.62 (Quantity-Distance) | Dary Class 9 | | |
| Method Hazard Class Compatibility | (Quantity-Distance) | Dary Class 9 | | |
| Method Hazard Class Compatibility | |) Class 9 | | |
| Hazard Class Compatibility | |) Class 9 | | |
| Hazard Class Compatibility | |) Class 9 | | |
| Compatibility | | Class 9 | | |
| • | Group | Group I | | |
| • | | | | |
| _ | | | | |
| Exudation None | | | | |
| | | | | |
| Rockwell Hardness, "R" Scale: (a) | | | | |
| 1/2 inch diameter Penetrator, 60 Kg Load: | | | | |
| Pellet | Specific | | | |
| Nc.* | Gravity | Ha-dness | | |
| 1 | 1.624 | 84 | | |
| 2 | 1.623 | 90 | | |
| 3 | 1.611 | 84 | | |
| 4 5 | | 80 75 | | |
| 6 | | 73 | | |
| 7 | 1.548 | 62 | | |
| B | 1.524 | 49 | | |
| Pellets (Lot in diameter | HOL-F-93) were and 3/4 inch hig | 1-1/2 inches | | |
| | 1/2 inch dis Pellet No.* 1 2 3 4 5 6 7 8 | 1/2 inch diameter Penetrato Pellet Specific No.* Gravity 1 1.624 2 1.623 3 1.611 4 1.600 5 1.590 6 1.571 7 1.548 | | |

Sensitivity of PB-RDX and 98/2 RDX/Stearic Acid fer ets* to Initiation by Type II Special Blasting Caps

| De11-4- | Gap | (Distance | e From | Bese of (| Cap to Po | ellet), 1 | nches |
|---|--------|-----------|--------|---------------|-------------|-----------|-------|
| Pellets | 0.250 | 0.300 | 0.350 | 0.400 | 0.450 | 0.500 | 0.7 |
| PB-RDX with Pellet Density 1.55 gm/cc | _ | | | | | | |
| Ho. of Trials | | 8 | 5 | 6 | 2 | 1 | 1 |
| Average Depuh of Plate Indentation, inches ** | 0.082 | J.090 | 0.087 | 0.080 | 0.080 | _ | _ |
| No. of Failures | 0 | 1 | 3 | 4 | 1 | 1 | 1 |
| PB-RDX with Pellet De.sity 1.60 gm/cc | | | | | | | |
| No. of Trials | _ 3 | 8 | 9 | 4 | 3 | 5 | 2 |
| Average Depth of Plate Indentation, inches ** | 0.090 | 0.089 | 0.087 | 0. 000 | 0.087 | 0.075 | |
| No. of Failures | 0 | 0 | 2 | 3 | 2 | 3 | |
| 98/2 FDX/Stearic Acid With Pellet Density 1.63 gm/cc | | | | | | | |
| No. of Trials | 5 | 3 | 5 | , | 5 | 5 | 5 |
| Average Depth of Plate Indentation, inches ** | 0.109 | 0.096 | 0.095 | 0.092 | 0.097 | 0.087 | |
| No. of Failures | 0 | 1 | 0 | 3 | 4 | 4 | 5 |

Performance of PB-RDX as Booster: (b, d)

Ten 2.75 inch HEAT MI Rocket Heads were unaffected in performance by storage at 71°C for 28 days. Thus, PB-RDX was not desensitized by contact with TNT-bearing explosives. Tetryl, similarly used, becomes desensitized when stored in bursting charges at elevated temperatures.

In addition, 108 modified M307Al 57 mm projectiles were fired for performance against armor. Each round contained a PB-RDX booster pellet. There was no evidence in these firings that the projectiles were inadequately boostered.

Mild steel plate $5" \times 5" \times 1"$.

Preparation:

The purchase description sheet for polystyrene-bonded RDX (X-PA-PD-1088, 25 October 1956) requires that the PB-RDX shall be a mixture of RDX, coated and surrounded by a homogeneous mixture of polystyrene and dioctylpathalate. The specified percentage of RDX shall consist of a mixture of 75% Type B, Class A RDX and 25% Type B, Class E RDX. The granulation of the unpressed composition shall be as follows:

| T | rough U. S. Standard Sieve No. | Minimum % | Maximum % |
|---|-----------------------------------|-----------|-----------|
| | 6 | 100 | |
| | 12 | 100 60 | |
| | 20 | | 2 |
| | 35 | | ō |

Two methods have been reported for the preparation of PB-RDX (Reference: Los Alamos Scientific Laboratory, Contract W-7405-Eng 36 with U.S. Atomic Energy Commission, Report No. IA-1448). The earlier method employed a Baker-Perkins type mixer to blend the components. This procedure gave a product with good pressing characteristics. However, the molding composition was nonuniform in granulation and tended to be dusty. The slurry method of PB-RDX preparation gave a product which was uniform, free-flowing and dustless. In addition, PB-RDX granulated by the slurry method exhibited satisfactory drying, handing and pressing characteristics.

The final procedure incorporating the better features found from the study of such variables as solvents, solvent/plastic ratios, lacquer addition and temperature, agitation, RDX particle size distribution, dispersants and rosin additive, was as follows (Reference c):

Forty-two and five-tenths grams (42.5 gm) of polystyrene and 8 cc dioctylphthelate were dissolved in 200 cc toluene in a lacquer dissolver. Steam was introduced into the jacket until the temperature reached 65°C. The lacquer was agitated constantly until it was ready to be added to the granulator. This lacquer contained a 1:4 ratio of plastic-plasticizer to toluene.

Four hundred and fifty grams (450 gm) of RDX and 4500 grams of H₂O (ratio 1:10) were added to the granulator. The agitator was set for 400 rpm and the temperature was raised to 75° C by introducing steam into the Jacket. The temperature differential between the lacquer solution and the RDX/water slurry was 5° to 10° C.

The lacquer solution was poured through the charging funnel into the granulator. As soon as the lacquer was added, a solution of gelatin in water was added, and the mixture was agitated until the lacquer was well dispersed in the RDX slurry (approximately 5 minutes). Granulation took place at this point. Steam was introduced again into the jacket to distill the solvent until the temperature reached 98°C. Cooling water was then run into the jacket to cool the batch to 40°C. The coated material from the granulator was collected on a Buchner funnel and dried in a tray at 70°C for 24 hours. Temperatures below 70°C did not furnish enough heat, but a temperature of 80°C produced stickiness and caking of PB-RDX.

Origin:

An explosive consisting of RDX coated with polystyrene plasticized with dicetyphthalate was initially developed in 1952 for the Atomic Energy Commission by Los Alamos Scientific Laboratory of the University of California (Contract W-7405-Eng 36 with U. S. Atomic Energy

PB-RDX

Commission, Report No. IA-1448). The specific formulation of 90/8.5/1.5 RDM/polystyrene/dioctylphthclate was subsequently standardised by Los Alamos. This emplosive, originally designated PBK, has been redesignated PB-RDM. The detailed requirements for the present polystyrene-bonded RDM(PB-RDM) are given in purchase description X-PA-PD-1088, 25 October 1956.

References; 53

- (a) B. J. Zlotucha, T. W. Stevens and C. E. Jacobson, <u>Characteristics of Polystyrene-Bonded RDK(PB-RDK)</u>, PATR No. 2497, April 1958.
- (b) A. J. Pascasio, The Suitability of a Bare PRX Booster Pellet in the 2.75 Inch ML HEAT Rocket Head, PATR No. 2271, November 1955.
- (c) J. L. Vermillion and R. C. Dubberly, Plastic-Bonded PNK, Its Preparation by the Slurry Method, Holston Defense Corporation, Control No. 20-7-16 Series A (PAC 1081), 5 March 1953.
- (d) C. J. Eichinger, Report on Cartridge HEAT 57 mm M307Al (Mod) with Modified Copper Liner, Aberdeen Proving Ground, Development and Proof Services, First Report on OC Project TA3-5204, October 1957.

⁵³See footnote 1, page 10.

Pentserythritol Trinitrate (PETRIN)

| Composition: | Melecular Weight: (C5H9N3O10) | 271 | | | |
|---|---|--------------|--|--|--|
| C 22.1 | Oxygen Belence: CO ₂ % CO % | -2 7 | | | |
| H 3.3 HOCH ₂ — C— CH ₂ ONO ₂ N 15.5 | Density: gm/cc | 1.54 | | | |
| O 59-1 | Molting Point: *C | 26 to 28 | | | |
| C/H Ratio 0.141 | Freezing Point: *C | | | | |
| Impact Sensitivity, 2 Kg Wr: | Beiling Point: *C 4 mm Hg Decomposes | 130 | | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 5 to 10 Sample Wt, mg 38 | Refrective Index. no. no. no. | | | | |
| Friction Fundulum Test: Steel Shoe Fiber Shoe | Vocuum Stability Test: cc/40 Hrs, at 90°C | 0.5 | | | |
| Riffe Bullet Impact Test: Trials % Explosions Partials | 100°C 120°C 135°C 150°C | 2.54 to 5.69 | | | |
| Burned Unoffected | 200 Grem Bomb Sand Test: Sand, gm | | | | |
| Explosion Temperature: "C Seconds, 0.1 (no cap used) 1 5 10 15 | Sensitivity to initiation: Minimum Detonating Charge, grn Mercury Fulminate Lead Azide Tetryi Ballistic Marker, % TNT: | | | | |
| 20 | Trough Toot, % TNT: | | | | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Sent Test: Method | | | | |
| 160°C Heet Test: % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs Explosion in 100 Hrs | Condition Confined Density, gm/cc Brisance, % TNT | | | | |
| Flemmobility Index: | Detenation Rate: Confinement | | | | |
| Hygrescapicity: % | Continement Condition Charge Diameter, in. | | | | |
| Volatility: | Density, gm/cc Rate, meters/second | | | | |

Pentaerythritol Trinitrate (PETRIN)

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 100: | |
|--|--|--------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cone | • |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | Color: | 17.14. |
| For TNT | Caller | Whi te |
| For Subject HE | | |
| | Principal Uses: Explosive, propellant igniter ingredient | i or |
| 3 inch HE, M42A1 Projectile, Let KC-5: | 28 | |
| Density, gm/cc | | |
| Charge Wt, Ib | | |
| Total No. of Fragments: | Method of Looding: | |
| For TNT | monage. | |
| For Subject HE | | |
| | Leeding Density: gm/cc | |
| Fragment Velocity: ft/sec | | |
| At 9 ft At 251/4 ft | Storege: | |
| Density, gm/cc | | |
| | Method | Dry |
| Sleet (Relative to TNY): | Hazard Class (Quantity-Distance) | |
| Air: | Compatibility Group | |
| Peak Pressure | | |
| Impulse - | Exudation | None |
| Energy | | |
| Air, Con.ined: | PETRIN esters are listed in remainded and most of these esters have been | , , |
| Impulse | have explosive properties. | |
| Under Water: | An infrared spectrophotometric | |
| Pegh. Pressure | was developed for the determination acetone content of PETRIN (ref c) | |
| Impulse | sample of PETRIN is dissolved in | |
| Snergy | and the volume increased to 25 mi | lliliters in |
| | a volumetric flask. The acetone the PETRIN solution is determined | |
| Underground: Peak Pressure | in a 0.5 absorption at 5.82 | mm cell. A |
| Impulse | double beam method is used with a cell containing chloroform and ac | |
| Energy | PETRIN. The quantity of the latte | |
| Absolute Viscosity, poises: | carefully adjusted to give a good | belance be- |
| Temp, 17°C 14.8 | tween the test sample and reference the strong PETRIN peak at 6.02 at | |
| 23°C 4.3 28°C 3.0 | | ···· |
| 38°C 1.2 | Heat of: | |
| | Explosion, callum | 1204 |

Explosion, cal/gm

1204

Preparation:

| с(сн ⁵ он) [†] + | знио з | H ^S SO [†] | OHCH ⁵ c(CH ⁵ MO ³ , ³ | + | 3H2 () |
|--------------------------------------|----------------|--------------------------------|--|---|---------------|
| pentaerythritol | nitric scid | sulfuric acid | pentaerythritol trinitrate | | water |
| MW 136 | MW 63 | MW 98 | MW 271 | | MW 18 |

The earlies procedure used for the manufacture of PETRIN was that developed at Alleghany Ballistics Laboratory. In this process, called the "A process," 80% HNO; and the solid pentaerythritol were charged to the reactor and 80% H₂SO₄ was added slowly at a rate to permit control of temperature at 0° to 5°C. This mixture was held for a 2-1/2-hour reaction period, then drowned in water and filtered to give a cake containing both the tri- and tetra-nitrates of pentaerythritol. The cake was dissolved in acetone and neutralized in solution with ammoniu carbonate, after which the PETN and precipitated by the addition of water. After filtration, the PETRIN was recovered from the filtrate by stripping off the solvent under vacuum. Yields by this process averaged about 40%.

An improved process, called the "B process," used the same primary reaction procedure but a different work-up procedure. After the reaction holding period, water was added to dilute the mixed acid and the batch was extracted in situ with methylere chloride. The organic layer was separated, neutralized with aqueous sodium bicarbonate, and stripped of methylene chloride under vacuum to yield the product directly. Yields by this process were about 50% and quality of the product was much improved over that of the "A process."

The "C process," currently in use, involves essentially the simultaneous synthesis and extraction of PETRIN from the reaction mixture. Methylene chloride approximately equal to the total weight of the other components is added to the reaction mixture before the sulfuric acid. After a satisfied time following the addition of sulfuric acid, the solvent is removed and replaced by fresh solvent one or more times. The combined extracts are neutralized and concentrated. Because of their initially relatively large volume, PETN __s_ be removed by filtration from the concentrated PETRIN solution before the final solvent is stripped. Yields by this process have been 60% to 65%.

Origin:

The nitration products of pentaerythritol or its derivatives containing not more than three NO₂ groups were petented for use as explosives, propellants or ignition materials in 1936 (German Patents 638,432 and 638,433; CA 31, 1212 (1937)).

A process in which pentaerythritol monoacetate was converted to pentaerythritol trinitrate monoacetate, which was then sapenified under carefully controlled conditions to PETRIN, was reported in 1954 (N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 70, 1304). THRIN was also prepared by the nitration of pentaerythritol with a mixture of 80% HMO₃ and 80% H₂SO₄ in 1955 (A. 7. Camp, N. S. Marans, D. E. Elrick and R. F. Preckel, J Am Chem Soc 77, 751).

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Pentserythritol Trinitrate (PETRIN)

References:54

- (a) Robm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Trinitrate Monoscrylate and Petrin Acrylate Propellants, 12 Mar. 1956.
- (b) E. Berlow, R. H. Barth and J. E. Snow, The Pentaerythritols, ACS Monograph No. 136, p. 65, Reinhold Publishing Corporation, New York, 1958.
- (c) R. H. Pierson, An Infrared Spectrophotometric Method for Determination of Acetone Content of Pentaerythritoltrinitrate, U.S. Havel Ordnance Test Station Report ROTE 1877, MAYORD Report No. 5649, 3 February 1958.

⁵⁴See footnote 1, page 10.

Pentaerythritol Trinitroacrylate (PETRIN Acrylate) [Trinitroxypentaerythritol Acrylate]

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| Composition: | Melecular Weight: (C8H ₁₁ N ₃ O ₁₁) 325 |
|--|---|
| C 29.5 | Oxygen Belence: |
| H 3.4 CH2CNO2 | CO ₂ %5¼12 |
| т 3 сн ⁵ = сл-со ⁵ сн ⁵ с-сн ⁵ оио ⁵ | -12 |
| N 12.9 | E ensity: gm/cc |
| 0 54.2 CH20NO2 | Melting Point: *C 78 to 79 |
| C/H Ratio 0.239 | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: | Beiling Point: *C |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | Refrective Index, no |
| Picatinny Aisenal Apparatus, in. | |
| Sample Wt, mg | n _m |
| | n _m |
| Priction Pendulum Test: | Vacuum Stability Test: |
| Steel Shoe | cc/40 Hrs, at |
| Fiber Shoe | 90°C |
| Riffe Bullet Impact Test: Trials | 100°C |
| • | 120°C |
| % Explosions | 135°C |
| Partials | 150°C |
| Burned | 200 Grem Bomb Send Tert: |
| Unaffected | Sand, gm |
| Explosion Temperature: °C | Sensitivity to Initiation: |
| Seconds, 0.1 (nu cop used) | Minimum Detonating Charge, gm |
| 1 | Mercury Fulminate |
| 5 | Lead Azide |
| 10 | Tetryl |
| 15 | Ballistic Morter, % TNT: |
| 20 | Trougi Test, % TNT: |
| 75°C International Host Test: % Loss in 48 Hrs | Plate Deat Test: |
| The state of the s | Niethod |
| 100°C Most Test: | Condition |
| % Loss, 1st 48 Hrs | Confined |
| % Loss, 2nd 48 Hrs | Density, gm/cc |
| Explosion in 100 Hrs | Brisance, % TNT |
| Flammability Index: | Detenci'na Rate: |
| | Confinement |
| Hygroscopicity: % N11 | Condition |
| 74. | Charge Diameter, in. |
| Volatility: | Density, gm/cc |
| · | Rate, meters/second |

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Pentaerythritol Trinitroscrylate (PETRIN Acrylate)

| regmentation Test: | Shaped Charge Effectiveness, TNT | == 100 : | |
|--|----------------------------------|--------------------------------|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones St | eel Concs | |
| Density, gm/cc | Hole Volume | | |
| Charge Wt, Ib | Hole Depth | | |
| Total No. of Fragments: | Color: | White | |
| For TNT | | HIII CG | |
| For Subject HE . | Principal Uses: Ingredient of | composite | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | rocket propel | lants · | |
| Density, gm/cc | | | |
| Charge Wt, Ib | | | |
| Total No. of Fragmonts: | Method of Leading: | | |
| For TNT For Subject HE | | | |
| | Looding Density: gm/cc | | |
| agment Velocity: ft/sec | | | |
| At 9 ft At 251/4 ft | Storage: | | |
| Density, gm/cc | | | |
| | Method Dry at tempe | ratures below melting point | |
| est (Reletive to TNT): | Hazard Class (Quantity-Distance) | | |
| Air: | Compatibility Group | | |
| Peak Pressure | | | |
| Impulse | Exudation | None | |
| Energy | | | |
| Air, Conficad: | . Heat of: | | |
| Impulse | Combustion, _i./gm | 292 3 | |
| Ada dan Salanan | Explosion, callem | 791 | |
| Under Woter: Peak Pressure | | | |
| im ulse | | | |
| Energy | | | |
| Underground: | | | |
| Peak Pressure | | | |
| Impulse Energy | | | |
| Carry | | | |
| | | | |
| | | | |
| | | | |

Pentaerythri a irinitroscrylate (PETRIN Acrylate)

(a) Preparation: HOCH2C(CH2NO3)3 $CH^5 = CHCOCI$ с₆н₅и(сн₃)₂ pentaerythritol trinitrate (PETRIN) acrylyl chloride dimethyl aniline MW 271 MW 90.5 MW 121 $(o^{5}NOCH^{5})^{3}CCH^{5}OCCH = CH^{5}$ c₆H₅N(CH₃)₂HC1 € pentaerythritol trinitrate monodimethylanine acrylate (PETRIN acrylate) MW 325 hydrochloride

The original synthesis for PETRIN acrylate employed trifluoroacetic anhydride and glacial acrylic acid as the acrylation agent for PETRIN. These two materials were charged to a reaction vessel and the initial reaction was controlled by the slow addition of PETRIN at a temperature of 10° to 15°C. Following a period of one hour, the batch was drowned in water, precipitating the PLIRIN acrylate. This solid was separated by filtration, dissolved in chloroform, and neutralized in solution with sodium bicarbonate. The product was then crystallized during a period of 16 hours at 0°C and dried under vacuum to remove traces of solvent. The yield for this process was about 60%.

A significant improvement in yield (to about 74%) and purity (approximately 96%) was realized by the substitution of methanol for chloroform and crystallization of the product from the solution without neutralization, residual acid being removed by washing the filter cake with water.

Because of the high cost and hygroscopic nature of trifluoroacetic anhydride, a new process, based on dimethylaniline and acrylyl chloride, was considered. This process is currently under development in one Rohm and Haas Chemical Processing facilities and is not considered optimum. Yields averaged 46% and product purities averaged 93.5%.

PETRIN Acrylate Propellants:

PETRIN acrylate could be used as a monopropellant because it has a specific impulse of 214 lb-sec/lb and a burning rate of 0.2 in/sec. The addition of an exidizer increases both the impulse and burning rate.

A composition which presently appears most promising is as follows:

| | Compos1 | tion NM |
|-----------------------------------|---------|----------------------------|
| PETRIN acrylate (> 97% purity), % | 34.3 | (binder) |
| Triethylene glycol frinitrate, % | 11.8 | (plasticizer) |
| Glycol diacrylate, % | 2.9 | (crosslinker) |
| Ammonium perchlorate, % | 51.0 | (oxidizer) |
| Hydroquinone, % | 0.014 | (polymerization inhibitor) |

Measured specific impulse 238 lb-sec/lb, at density of 1.3.

Reference:55

(a) Rohm and Haas Company, Redstone Arsenal Division, Process for the Manufacture of Pentaerythritol Tetranitrate Monoacrylate and Petrin Acrylate Propellants, 12 March 1956.

⁵⁵See footnote 1, page 10.

Pentolite, 50/50; 10/90

| Composition: | | | Molecular Weight: | 50/50 265 | 10/90 234 |
|--|---------------|-------------|--------------------------------------|--------------|---------------|
| | | [| Oxygen Belence: | | |
| PETN 50 | 10 | 1 | CO ₂ % | -42 | -68 |
| TNT 50 | 90 | l | co % | - 5 | -21 |
| 101)0 | ,~ | | Density: gm/cc | 1.65 | 1.60 |
| | | j | Melting Point: °C | | 76 |
| C/H Ratio | | Ī | Freezing Point: *C | | |
| Impect Cereltivity, 2 Kg Wt: Bureriu of Mines Apparatus, ci | 50/50 m 34 | 10/90 65 | Boiling Point: *C | | |
| Somple Wt 20 mg | _ | | Refrective Index, no | | |
| Picatinny Arsenal Apparatus, | in. 12 15 | 14 | n _s | | |
| Sample Wt, mg | 15 | 10 | n ₂₀ | | |
| Friction Pendulum Test: | | | Vecnum Stability Test: | 50/50 | 10/90 |
| Steel Shoe | Un | affected | cc/40 Hrs, at | | |
| Fiber Shoe | ប្រធ | affected | 90°C | | |
| | | | 100°C | 3.0 | 3.0 |
| Riffe Bullet Impact Test: 25 Tri | ols, 50/50 | | 120°C | 11+ | 11+ |
| Explosions 7 | 6 2 | | 135°C | | |
| Portials 2 | | | 150°C | •• | |
| | 0 | 1 | 900 C B C 4 T | | |
| | 8 | | 200 Grem Bemb Send Test: Sond, gm | 55.6 | 49.5 |
| - Charrected | | | | | |
| Explosion Tumperature: | ·c, 50/50 | | Sensitivity to Initiation: | | <u>50/50</u> |
| Seconds, 0.1 (no cap used) | 290 | | Minimum Detonating Ch | arge, gm | |
| _ | 26€ | | Mercury Fulminate | | 0.19* |
| | 220 | ļ | Lead Azide | | 0.13* |
| | 50# | | Tetryl *Alternative initiation | ng charges | |
| | 197 | | Sallistic Morter, % TNT: | (a) | 126 |
| 20 > | 190 | Ì | Trauzi Test, % TNT: | (b) | 122 |
| 75°C International Host Test: | | | | (c) | |
| % Loss in 48 Hrs | | | Plate Dent Test: Method | (0) | Б |
| | | | Condition | | Cast |
| 100°C Heat Test: | <u>50/5</u> | _ | Condition | | No |
| % Loss, 1st 48 Hrs | 0.0 | o | - | | 1.66 |
| % Loss, 2nd 48 Hrs | 0.: | 2 | Density, gm/cc | | 121 |
| Explosion in 100 Hrs | No | ne | Brisance, % TNT | | |
| Flemmability Index: Will not | continue to | hurn | Detenation Rate: | | lion e |
| Assessment and a service of the serv | continue so | 541.1 | Confinement | | Cast |
| Mysessessicity: 04. | 0/50 10 | /90 | Condition | | |
| Hygrescopicity: % 2 30°C, 90% RH N | one N | one | Charge Diameter, in. | | 1.0 |
| Voletility: | | | Density, gm/cc | | 1.66 |
| · | | | Rate, meters/second | | 7465 |

Pentolite, 50/50: 10/40

| | 0/50 Decemposition Equation: ast Oxygen, atoms/sec | |
|--------------------------------|--|--------|
| | 00 (Z 'sec) | |
| | Heat, kilocalorie/mole | |
| Wax, gm | (AH, kcal/mal) Temperature Range, °C | |
| | .65 Phase | |
| Density, gm/cc 1.60 | | |
| Heat of: Combustion, cal/gm | Armor Plate Impact Test: 50 | /50 |
| Explosion, cal/gm | 1220 60 mm Morter Projectile: | |
| Gas Volume, cc/gm | | .70 |
| Formation, cal/gm | Aluminum Fineness | |
| Fusion, cal/gm | | |
| | 500-lb General Purpose Bombs: | |
| Specific Heat: cal/gm/°C | Plate Thickness, inches | |
| | , | |
| | 1 | |
| | $\frac{n_4}{n_4}$ | |
| | 11/4 | |
| | 134 | |
| Surning Rate: cm/sec | | |
| Livy 36% | Romb Drop Test: | |
| Thermal Conductivity: | T7, 2000-th Semi-Armor-Piercing Bomb vs Con | erato: |
| cal/sec/cm/°C | 17) 2000-m Sermi-Minist-1 mining noung 40 min | |
| Coefficient of Expansion: | Max Sufe Drop, ft | |
| Linear, %/°C | 500-lb General Purpose Bomb vs Concrete: | |
| Volume, %/°C | Height, ft | |
| | Trials | |
| Herdness, Mohs' Scele: | Unarfected | |
| | Low Order | |
| Young's Modulus: | High Order | |
| E', dynes/cm² | Trigger writer | |
| E, lb/inch² | 1000-lb General Purpose Bomb vs Concrete: | |
| Density, gm/cc | | |
| | Height, ft | |
| | -2200 Trials | |
| Density, gm/cc | 1.65 Unoffected | |
| Vapor Pressure: | Low Order | |
| °C mm Mercury | High Order | |
| | | |
| | | |

Pentolite, 50/50; 10/90

| Fragmentation Test: | <u>50/50</u> | Sheped Charge Effectiveness, TNT = 1 <u>50/50</u> 10/90 50/50 | 90: 25/75 |
|---------------------------------------|--------------|--|----------------------|
| 90 mm HE, M71 Projectile, Let WC-1 |) 1: | Gloss Cones(1) Steel (| |
| Density, gm/cc | 1.65 | Hole Volume 157 105 149 | 119 |
| Charge Wt, Ib | 2.147 | Hole Depth 116 116 131 | 119 |
| Total No. of Fragments: | | Color | v-vhite |
| For TNT | 703 | Color: Yello | 4111 06 |
| For Subject HE | 963 | Principal Uses: Shaped charges, | hureting |
| 3 inch HE, M/12A1 Projectile, Let KC- | 5: | charges, demolit | |
| Density, gm/cc | 1.65 | " | |
| Charge Wt, Ib | 0.872 | | |
| Total No. of Fragments: | | Adah ad ad b andhan | |
| For TNT | 514 | Method of Leading: | Cast |
| For Subject HE | 6 50 | | |
| | | Looding Density: gm/cc | 50/50 10/90 |
| Fragment Velocity: ft/sec | | | 1.65 1.60 |
| At 9 ft At 251/2 ft | 2810 2580 | Sterege: | |
| Density, gm/cc | 1.66 | Method | Dry |
| | | | • |
| Blest (Relative to TNT): | (e) | Hazard Class (Quantity-Distance) | Class 9 |
| Ale: | | Compatibility Group | Group I |
| Peak Pressure | 105 | S. data | |
| Impulse | 107 | Exudation | |
| Energy | | Compatibilities and his Made 2 | |
| Air, Confined: | | Compatibility with Metals: | |
| Impulse | | Dry: Copper, brass, aluminum magnesium-aluminum alloy, mild | |
| | | with acid-proof black paint, and | d mild steel |
| Under Weter: | | plated with copper, cadmium or | |
| Peak Pressure | | affected. Zinc plated steel is affected. | only slightly |
| Impulse | | | |
| Enurgy | | we': Stainless steel, alumin steel conted with acid-proof bloom | |
| Underground: | | not sife ted. Copper, brass, m | gnesium, mag- |
| Peak Pressure | | nesium-aluminum alloy, mild stee | |
| Impulse | | steel plated with copper, cadmit nickel are slightly affected. | AM, ZIAC OF |
| Energy | | Effect of Temperature on | (h) |
| Eutectic Temperature, OC: | 76 | Rate of Detonation: | 50/50 |
| gm PETN/100 gm TNT | | | -54 21 |
| 76°C | 13.0 | | .67 1.66 +70 7440 |
| 95°c | 28.3 | Mate, m/ sec | 10 1440 |

Pentolite, 50/50; 10/90

Preparation:

Pentolite is manufactured by either the slurry method or coprecipitation of PETN and TNT. In the slurry method PETN, in water, is stirred and heated above 80°C. TNT is added and when molten, it coats the particles of PETN. The slurry is cooled with rapid stirring and the separated granules are collected on a filter and dried below 75°C.

In opprecipitation, PEIN and INT are dissolved separately in acctone. The solutions are mixed and the explosives are precipitated simultaneously by pouring the mixed solution into cold water under vigorous agitation. The precipitated solid is collected on a filter and dried in air.

Origin:

Standardized during World War II, with the 50-50 PETN/INT mixture being the more important for bursting charges and booster-surround charges.

References: 56

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 57%6, 27 December 1945.
- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Revision, NAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (d) L. C. Smith and S. R. Walton, A Consideration of RDE/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (e) W. R. Tomlinson, Jr., Elast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (f) Eastern Laboratory, du Pont, Investig.: on of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W672-ORD-5723.
- (g) Eastern Laboratory, du Pont, investigation of Cavity Effect, Final Report, Contract W-672-ORD-5723, E. Lab, du Pont, 18 September 1943.
- (h) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
 - (i) Also see the following Picatinny Arsenal Technical Report on Pentolite:

| <u>o</u> | 1 | 2 | 3 | 4 | 2 | <u>6</u> | 7 | 8 |
|----------------------|----------------------|----------------------|------------------------------|--------------|------|----------------------|----------------------|------------------------------|
| 1360 1420 1570 | 1291 1451 1651 | 1212 1262 1372 | 1133 1193 1213 1363 | 1284 2004 | 1325 | 1436 1466 1796 | 1477 1677 1737 | 1388 1598 1668 1838 |

⁵⁶See footnote 1, page 10.

PETN (Pentaerythritol Tetranitrate)

| Composition: | | Molecular Weight: (C5H8 | N ₄ 0 ₁₂) | 316 |
|--|-------------------|--|----------------------------------|--------------|
| 0NO ₂ | | Oxygen Velence: | | |
| | | CO ₂ % | | -10 |
| н 2.5 ^{СН} 2 | | CO % | | 15 |
| N 17.7 02NO-CH2-C-CH2 | -cno ₂ | Density: gm/cc Cr | ystal | 1.77 |
| o 60. 8 cH ₂ | | Melting Point: °C | | 141 |
| C/H Ratio 0.134 0NO ₂ | | Freezing Point: °C | | |
| Impact Sensitivity, 2 Kg Wt: | | Boiling Point: °C | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in Sample Wt, mg | 17 6 16 | Refrective Index, no | | |
| Friction Pendulum Test: | | Vacuum Stability Test: | | |
| Steel Shoe Cr | eckles | cc/40 Hrs, at | | |
| | affected | 90°C | | |
| | | - 100°C | | 0.5 |
| Riffle Sullet Impact Test: 5 Trials * | | 120°C | | 11+ |
| % | | 135°C | | 114 |
| Explosions 100 | | 1 | | |
| Partials 0 | | 150°C | | |
| Burned 0 | | 200 Grem Bomb Sand Test: | | |
| Unoffected 0 *4.80% moisture in samples | | Sand, gm | | 62.7 |
| Explosion Temperature: °C | | Sensitivity to Initiation: | | |
| Seconds, 0.1 (no cap used) 272 | | Minimum Detonating Ch | arge, am | |
| 1 244 | | Mercury Fulminate | | 0.17* |
| 5 Decomposes 225 | | Lead Azide | | 0.03* |
| 10 211 | | 1 | | • |
| 15 | | Tetry! *Alternative initiating | ng charge | 8. |
| 20 | | Ballistic Morter, % TNT: | (a) | 145 |
| FEOC Indon-Air-of Mana Trus | | Trouzi Test, % TNT: | (b) | 173 |
| 75°C International Heat Test: % Loss in 48 Hrs | 0.02 | Plate Lent Test: | (c) | |
| | J.0L | Method | | A |
| 100°C Heat Test: | | Condition | | Pressed |
| % Loss, 1st 48 Hrs | 0.1 | Confined | | Yes |
| % Loss, 2nd 48 Hrs | · - | Density, gm/cc | | 1.50 |
| | 0.0 | Brisance, % TNT | | 129 |
| Explosion in 100 Hrs | None | | | |
| Flammability Index: Will not continue | e to burn | - Detenation Rate: Confinement | | None |
| , | | 1 | | None |
| Hygroecopicity: % 30°C, 90% RH | 0.0 | Condition | | Pressed |
| | | Charge Diameter, in | | 1.00 |
| Volatility: | 0.0 | Density, gm/cc | | 1.70 |
| | V. () | Rate, meters/second | | 8 300 |

PETN (Pentaerythritol Tetranitrate)

| Booster Sensitivity Test: Condition | (c) Pressed | Decemposition Equation: (e) (e) (f) (f) (23.1 (20.6 1023.1 |
|--|----------------|--|
| Tetryl, gm | 5 | (Z/sec) Heat kilocalurie/male 47.0 50.9 52.3 |
| Wax, in. for 50% Detonation | | Heat, kilocalurie/male 47.0 50.9 52.3 (ΔH, kcal/mal) |
| Wax, gm | 3 | Temperature Range, °C 161-233 108-120 137-157 |
| Density, gm/cc | 1.6 | Phase Liquid Solid At melt |
| Heat of: Combustion, cal/gm | 1960 | Armor Plete Impact Test: |
| · · · · · · | 1 3 85 | |
| Explosion, cal/gm | 790 | 60 mm Morter Projectite: |
| Gas Volume, cc/gm | 383 | 50% Inert, Velocity, ft/sec |
| Formation, cal/grn | 303 | Aluminum Fineness |
| Fusion, cal/gm | | 500-lb General Purpose Bombs: |
| Specific Hest: cal/gm/°C | (d) | |
| | | Plate Thickness, inches |
| Room Temperature | 0.26 | |
| | | 1 |
| | | 11/4 |
| | | 11/2 |
| | | 13/4 |
| Eurning Rete: | | |
| cm/sec | | Bomb Drop Test: |
| Thermal Conductivity: cal/sec/cm/°C | | T7, 2000-lb Semi-Armor-Piercing Bomb vs Concrete: |
| Coefficient of Expansion: | | Max Safe Drop, ft |
| Linear, %/°C | | 500-lb General Purpose Bomb vs Concrete: |
| Volume, %/°C | | Height, ft |
| | | Trials |
| Herdness, Mohs' Scele: | 1.9 | Unaffected |
| | | Low Order |
| Young's Modulus: | | High Order |
| E', dynes/cm² | | 1 |
| E, lb/inch² | | 1000-lb General Purpose Bamb vs Concrete: |
| Density, gm/cc | | |
| | | —— Height, ft |
| Compressive Strength: Ib/inch ² | | Trials |
| | | Unaffected |
| Vaper Pressure: | | Low Order |
| °C mm Mercury | | High Order |
| | | |

AMCP 706-177

PETN (Pentaerythritol Tetranitrate)

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 1 | 90: | | | | |
|---|---|--|--|--|--|--|
| 99 man HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel (Hole Volume Hole Depth | Cones | | | | |
| Total No. of Fragments: For TNT | Color: | White | | | | |
| For Subject HE | | | | | | |
| 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Class A - Detonating fuse an | Principal Uses: Class A - Detonating fuse and boosters Class B - Priming compositions | | | | |
| Tetel No. of Fregments: For TNT For Subject HE | Mathod of Loading: | | | | | |
| ror subject the | Leading Density: gm/cc ps: x | 103 | | | | |
| Fregment Velocity: ft/sec At 9 ft | 1.37 1.58 1.64 1.71 1.7 | 0 40 | | | | |
| At 251/s ft Density, gm/cc | Storage: | •• . | | | | |
| | Me nod | Wet | | | | |
| Blact (Reletive to TNT): | Hazard Closs (Quantity-Distance) | Class 9 | | | | |
| Air: Peak Pressure | Compatibility Group | Group M (wet) | | | | |
| Impulse | Exudation | None | | | | |
| Energy | | | | | | |
| Air, Confined: | Bulk Modulus at Room Temperature (25°-30°C): | (1) | | | | |
| Under Weter: Peak Pressure | Dynes/cm ² x 10 ⁻¹⁰ Density, gm/cc | 4.60 1.77 | | | | |
| Impulse | | | | | | |
| Energy | | | | | | |
| Underground: Peak Pressure | | | | | | |
| Impulse | | | | | | |
| Energy | | | | | | |
| | | | | | | |

Compatibility with Metals:

<u>Dry:</u> Copper, brass, aluminum, magnesium, magnesium-sluminum alloy, stainless steel, mild steel, mild steel coated with acid-proof black paint and mild steel plated with copper, cadmium, nickel or zinc are not affected.

Wet: Stainless steel is unaffected and aluminum only vary slightly so after prolonged storage. Copper, brass, magnesium, magnesium-aluminum alloy, mild steel, mild steel costed with acid-proof black paint and mild steel plated with cadmium, copper, nickel or zinc are affected.

Sensitivity of PETN to electrostatic discharge, joules; Through 100 Mesh: (g)

Unconfined Confined

0.06

Solubility, grams of PETN per 100 grams (%) of: (h)

| | rethylene lcohol | Ace | tone | Ве | nzene | To | luene |
|----------------------|----------------------------------|---------------------------------------|----------------------------------|----------------------------|----------------------------------|---|---|
| °c | ž | <u>°c</u> | £ | °c | 纟 | °c | 2 |
| 0 20 40 60 | 0.070 0.195 0.115 1.205 | 0 20 40 60 | 14.37 24.95 30.56 42.68 | 0 20 40 80 | 0.150 0.450 1.160 7.900 | 0 20 40 60 80 100 112 | 0.150 0.430 0.620 2.490 5.850 15.920 30.900 |
| Methyl acetate | | Ether | | 8-Ethoxy-ethyl- acetate | | Chlorobenzene | |
| °c | £ | °c | ½ | <u>°с</u> | 2 | °c | 2 |
| 20 30 40 50 | 13 17 22 31 | 0 2 0 3 ¹ 4•7 | 0.200 0.340 0.450 | 20 30 40 50 | 1.5 4.1 7.6 11.2 | 20 30 40 50 | 0.35 2.8 6.1 9.2 |

| Ethylenedichloride | | Methanol | | Tetrachloroethane | | <u>Carbon</u> tetrachloride | |
|--------------------|-------------------|----------------|---------------------|-----------------------------|------------------------------|--------------------------------|----------------------------------|
| <u>°c</u> | ½ | °c | <u> </u> | <u> 20</u> | <u>\$</u> | <u>°c</u> | 2 |
| 10 30 50 | 0.9 1.5 2.6 | 20 40 60 | 0.46 1.15 2.6 | 20 30 40 50 | 0.18 0.27 0.40 0.58 | 20 30 40 50 | 0.096 0.108 0.118 0.121 |

| AMCP 7 | 06-177 | PEIN (| PETN (Pentar v'aritol Tetran trate) | | | | | |
|-------------|----------------|----------|-------------------------------------|-------------|------------|-----------|------|--|
| Isoproranol | | Isobu | Isobutanc) | | Chloroform | | TNT | |
| <u>°c</u> | £ | °c | 2 | <u>°c</u> | £ | <u>°c</u> | Z | |
| 15 | 0.05 | 20 | C 27 | 20 | 0.09 | 80 | 19.3 | |
| 20 | 0.0 | 30 40 | 0.31 | | | 85 | 25.0 | |
| 30 40 | 0.15 | 40 | 0.39 | | | 90 | 32.1 | |
| 40 | 0.36 | 50 | 0.52 | | | 95 | 39.5 | |
| 50 | 0.46 | | | | | 100 | 48.6 | |
| | | | | | | 105 | 58.2 | |
| | Eutetic of the | | N-TNT is abo | out 13% PET | 5 | 110 | 70.0 | |
| | and 87% TNT at | 76°C. | | | | 115 | 87.8 | |
| | | | | | | 120 | 115 | |
| | | | | | | 125 | 161 | |

Preparation:

(Nitroglycerin and Nitroglycerin Amplosives, Naoum)

8HCHO + CH3CHO + Cm(OH)2 \longrightarrow 2C(CH2OH)4 + Cm(HCOO)2 C(CH2OK)4 + 4HNO3 \longrightarrow C(CH2OHO2)4 + 4H2O

1. In this preparation 1940 gm of formsldehyde and 600 gm of aceteliehyde are dissolved in 90 liters of vater containing 1600 gm suspended slaked lime. The reaction is complete in about 3 weeks if agitated several times a day. The solution is filtered, the calcium formate precipitated with omalic acid, filtered off, and the water removed under reduced pressure. On cooling the mother liquor about 1200 gm crude pentaery-thritol, melting point 2350-2400c are obtained. Purification is resudily effected by stirring with a little alcohol, filtering and recrystallization from water.

2. To 400 cc of strong white nitric cid, are added 100 gm of pentaerythritol (through 50 mesh), at 5°C or below, under good about ition. After addition is complete stirring, at 5°C, is continued for 15 minutes. The mixture is drowned in 3 liters of ice-water, filtered, the product washed free of acid with water and then digested 1 hour in 1 liter of hot 0.5% sodium carbonate solution. The product is filtered, and recrystallized from acetone.

Origin:

PETN was known as an explosive in 1894 when it was proposed as an addition to smokeless powders to raise their flammability and case of combustion (German Patent 81,664 (1894). Modern methods of preparation are described by Vignon and Gerin (Compt rend 133, 590 (1901) and German Patent 265,025 (1912) and A. Stettbacher (Z ges Schiess - Sprengst frv 11, 112, 102 (1916) and 24, 259 (1929)). PETN was not used on a practical basis until after World War I.

Destruction by Chemical Decomposition:

PETN is a compose by dissolving in 8 times its weight of technical grade acetone and burning the solution i a shallow container. If preferred, where the acetone solution to 40° C, stir and add 7 parts by weight, to each part of PPTN, of a solution of 1 part sodium sulfide (Ma_2 S·9 H_2 O) in 2 parts water heated to 80°C. The agreeus solution should be added at such a rate that the acetone solution does not buil. After mixing is complete continue stirring for challed boxin.

PETN (Pentaerythritol **etranitrate)

References:57

- (a) L. C. Smith and F. G. Hyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Testu; Performance Tests. OSRP Report No. 5746, 27 December 1945.
 - (b) Ph. Naoum, Z ges Schiess Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
 - (d) International Critical Tables.
- (e) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind & Eng Chem, (June 1956), pp. 1090-1095.
- (f; A. J. B. Robertson, "The Thermal Decomposition of Pentaerythritol Tetranitrate, Nitroglyceri:. Ethylenediamine Dinitrate and Ammonium Nitrate," J Chem Ind 67, 221 (1948).
- (g) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U.S. Dept of Int, Bureau of Mines, RI 3852, 1946.
 - (h) Various sources in the open literature.
- (i) W. S. Cramer, <u>Bulk Compressibility Data on Several High Explosives</u>, NAVORD Report No. 4380, 15 September 1956.
 - (j) Also see the following Picatinny Arsenal Technical Reports on PETN:

| <u>o</u> | <u>1</u> | 2 | - 3 | 4 | 2 | <u>6</u> | 1 | <u>8</u> | 2 |
|---|--|--|--|-----------------------------|--|--|---|--|--------------------------------------|
| 760 1170 1260 1290 1300 1320 1360 2380 1390 1430 1450 1570 | 1041 1311 1381 1451 1561 1611 1651 | 772 922 1182 1192 1212 1262 1342 1352 1372 1452 | 843 863 1063 1133 1253 1343 1493 1533 | 904 1274 1284 1414 | 1305 1325 1445 1705 1885 2125 | 1246 1276 1316 1376 1446 1456 1466 1556 | 407 527 857 1247 1517 1617 1737 1797 | 318 633 1238 1318 1388 1568 1568 1598 1830 2178 | 1429 1489 1489 1559 2179 |

^{*}See footsote 1, page 16.

Picramide (TNA) (2,4,6-Trinitroaniline)

| Composition: | Aolecular Weight: (C6H4N4O6) | 228 |
|---|----------------------------------|-------------------|
| c 31.5 | Oxygen Belense: | _ |
| | CO ₂ % | -56 |
| H 1.8 o_2 N \sim N o_2 | CO % | -14 |
| N 24.5 | Density: gm/cc Crystal | 1.76 |
| o 42.2 NO ₂ | Melting Point: °C | 189 to 190 |
| C/H Ratio 0.500 | Freezing Point: 'C | |
| Impocr Sensitivity, 2 Kg Wt: | Boiling Point: *C Decomposes bef | ore boiling point |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | Refractive Index, no | |
| Picatinny Arsenal Apparatus, in. 23 | n _m | |
| Sample Wt, mg 20 | | |
| | n ₂₀ | |
| Friction Pendulum Test: | Vacuum Stability Test: | |
| Stee! Shoe | oc/40 Hrs, at | |
| Fiber Shoe | 90°C | |
| Rifle Bullet Impect Tess: Trials | 100°C | 0.9 |
| • | 120°C | |
| % Explosions | 135°C | |
| Partic's | 150°C | |
| Burned | 200 Grem Bomb Sand Test: | |
| Unaffected | Sand, gm | 48.2 |
| | | |
| Explosion Temperature: °C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | |
| 5 | Mercury Fulminate | 0.30 |
| 10 | Leod Azide | Ų. 3 0 |
| 15 | Tetryl | |
| 20 | Ballistic Morter, % TNT: | 100 |
| | Treux! Test, % TNT: | 107 |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: Method | |
| | Condition | |
| 100°C Heet Test: | Confired | |
| % Loss, 1st 48 Hrs | | |
| % Loss, 2nd 48 Hrs | Density, gm/cc | |
| Explosion in 100 Hrs | Brisance, % TNT | |
| A | Detonation Rate: | |
| Flemmability Index: | Confinement | Non e |
| AA 1 to 00 | Condition | Pressed |
| Hygroscopicity: % | Charge Diameter, in. | 0.5 |
| | Density, gm/cc | 1.72 |
| Voletility: | | |

AMCP 706-177

Picramide (TNA) (2,4,6-Trinitroaniline)

| Fragmentation Test: | Shaped Charge Effectiveness, TNT == 100: | | | |
|---|---|--------------------|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hole Volume Hole Depth | | | |
| Total No. of Fragments: For TNT | Color: Yel | Yellow | | |
| For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: High temperature heat resistant explosive | | | |
| Total No. of Fragments: For TNT | Method of Loading: | Pressed | | |
| For Subject HE Fregment Velocity: ft/sec | Leading Density: gm/cc At 50,000 psi | 1.72 | | |
| At 9 ft At 25½ ft | Storega: | | | |
| Density, gm/cc | Method | Dry | | |
| Slest (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 | | |
| Air: Peak Pressure Impulse Energy | Compatibility Group Exudation | Group I | | |
| Air, Centined: Impulse Under Weter: Peok Pressure Impulse Energy | Solubility: Insoluble in water, slightly soluble alcohol and ether. Soluble in hot acetic acid, hot ethyl acetate and and acetone. Heat of: | glacial | | |
| Underground: Peak Pressure Impulse Energy | Combustion, cal/gm (a) Explosion, cal/gm Formation, cal/gm (a) | 2962 564 131 | | |

Picramide (TNA) (2,4,6-Trinitroaniline)

Preparation:

Five grams of picryl chlumide were dissolved in 180 milliliters of absolute methanol. The solution was then satureled with anhydrous, gaseous ammonia. The time required was approximately 30 minutes. The amino derivative precipitated in 75% yield (3.5 gm) melting at 190° C (literature MP 189° C).

Origin:

Picramide (2,4 o-trinitroaniline) was first prepared in 1854 by Pisani who treated picryl chloride with am onium carbonate (CR 39, 853). The use of picramide, as a brisant explosive, was patended by Chemische Fabrik Griesheim 26 May 1894 (German Patent 84,628). Meisenheimer and Patzig reseted trinitrobenzene with hydroxylamine in cold alcohol solution to obtain picramide (Ber 39, 2534 (1906)). Witt and Witte obtained the compound by nitrating a solution of aniline in glacial acetic acid or concentrated H₂SO₄ at about 5°C with concentrated HNO₂ (Ber 41, 3091 (1908)). Holleman gives details of the prep ation from p-nitroaniline and from acetanilide (Rec trav chim 49, 112 (1930)).

Reference: 58

(a) William H. Rinkenbach, "The Heats of Combustion and Formation of Aromatic Nitro Compounds," J Am Chem Soc 52, 116 (1930).

⁵⁸See footnote 1, pag .0.

Picratol, 52/45

| Composition: | | Molecular Weight: | <u>236</u> |
|---|------------|-------------------------------|--------------|
| Explosive D 52 | | Oxygen Balance: | 6 . |
| | | CO. % CO % | -63 -19 |
| INT 43 | | | |
| | | Density: gm/cc Cast | 1.62 |
| | | Malting Point: 'C | |
| C/H Ratio | | Freezing Point: "C | |
| Impact Sansitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | 100+ | Boiling Point: 'C | |
| Sample Wt 20 mg | | Refractive Index, no | |
| Picatinny Arsenal Apparatus, in. | 17 19 | ns | |
| Sample Wt, mg | 17 | n _m | |
| Friction Pendulum Test: | | Vacuum Stability Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, | |
| Fiber Shoe | Unaffected | 20 ℃ | |
| Rifle Bullet Impact Test: Trials | | 100°C | 0.37 |
| • | | 120 °C | 0. 68 |
| Explosions 0 | | 135°C | |
| Partials 0 | | 150 C | 0.7 |
| Burned 40 | | 200 Gram Bemb Send Test: | |
| Unaffected 60 | | Sand, am | 45.0 |
| Explosion Temperature: | / | Sonsitivity to Initiation: | |
| Seconds, 0.1 (no cap used) 45 | | Min mum Detonating Charge, gm | |
| 1 35 5 Decomposes 39 | | Mercury Fulminate | |
| 5 Decomposes 28 | - | Leaa Azide | 0.20 |
| 10 26 15 26 | | Tetryl | 0.0. |
| 15 247 20 25 | | Ballistic Murter, % TNT: /13) | 100 |
| | | Trouzi Tost, % TNT; | |
| 75°C International Heat Test: % Loss in 48 Hrs | 0.0 | Plote Dent "ost: (:) | |
| | | Method | : |
| 100°C Hest Test: | | Condition | 8 € |
| % Loss, 1st 48 Hrs | 0.0 | Confined | Ge. |
| % Loss, 2nd 48 Hrs | 0.0> | Density, gm/cd | 1.13 |
| Explosion in 100 Hrs | Non-e | Brisunce, % TNT | ţ(h) |
| Flammability Index: | | Detenation Rate: (-) | |
| | | Confinement | : + |
| Hygrescepicity: % 30°€, 30% R | 4 0.02 | Condition | # E ' |
| | | Charge Diameter, in |) |
| Volatility: | | Density, gm/cc | |
| | | Rate, meters/second | 1.0 |

Picratcl, 52/48

| Fregmentation Test: | | Shaped Charge Effectiveness, TNT = 10 | y : |
|---------------------------------------|-----------------|--|----------------------|
| 90 mm HE, M71 Projectile, Lot WC-9 | 1: | Glass Cones Steel Co | ones |
| Density, gm/cc | 1.61 | Hole Volume | |
| Charge Wt, Ib | 2.075 | Hole Depth | |
| Total No. of Fragments: | | Color: Bros | wn-yellow |
| For TNT | 703 | Bron | MIT-YELLOW |
| For Subject HE | 76 9 | Principal Uses: AP, SAP projectiles | and bombs |
| 3 inch HE, M42A1 Projectile, Let KC-! | S : | and the same of th | 5 4.1 6 COMED |
| Density, gm/cc | 1.61 | j | |
| Charge Wt, Ib | 0.850 | | |
| Total No. of Fragments: | | Method of Loading: | Cast |
| For TNT | 514 | melines (* Essening. | Casc |
| For Subject HE | 487 | | |
| | | Loading Deveity: gm/cc | 1.62 |
| Fregment Velocity: ft/sec | 0500 | | |
| At 9 ft At 2514 ft | 2590 2320 | Storage: | |
| Density, gm/cc | 1.62 | | |
| | | Method | Dry |
| Blast (Relative to TNT): | | Hozard Crass (Quantity-Distance) | Class 9 |
| Air: | | Compatibility Group | Group I |
| Peak Pressure | 100 |) _ | |
| impulse | 100 | Exudation | None at 650 |
| Energy | | | |
| | | Preparation: | |
| Air, Confined: | | Picratol is made by heating TW | T to about |
| Impulse | | 90°C in a steam-jacketed melt ke | |
| Under Weter: | | sive D is added slowly, without pand the mixture stirred until un | |
| Peak Pressure | | position. This slurry is cooled | |
| impulse | | and poured into the appropriate | |
| Energy | | component. | |
| Underground: | | Origin: | |
| Peak Pressure | | Developed during World War II | |
| Impulse | | tive, "elt-loaded AP bomb and pro | ojectile fille |
| Energy | | Booster Sensitivity Test: | (c) |
| Bomb Drop Test: | | Condition | Cast 100 |
| T7, 2000-15 Semi-Armor-Pierc | ing | Tetryl, gm Wax, in. for 50% Detonation | 1.00 |
| Bomb vs Concrete: | | Density, gm/cc | 1.63 |
| | | f | |

Picratol, 52/48

References: 59

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.
 - (c) Also see the following Picatinny Arse: $\epsilon 1$ Technical Reports on Picratol:

 0
 5
 6
 I
 8
 9

 1470
 1885
 1466
 1737
 1838
 1729

 1796
 1797

 1956

⁵⁹See footnote 1, page 10.

| Composition: | | Molecular Weight: (C ₆ H | 3 ^N 3 ^O 7) | 229 | | |
|--|--------------------|-------------------------------------|----------------------------------|--------------------|--|--|
| C 31.5 | | Oxygen Belence: | | \ | | |
| | wa | CO ₂ % | | -45 -3•5 | | |
| H 1.3 02N | No ₂ | | | | | |
| N 18.3 |) | Density: gm/cc | Crystal | 1.76 | | |
| 0 48.9 Y | | Melting Point: °C | | 122 | | |
| C/H Ratio 0.656 | Freezing Point: °C | | | | | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | 85 | Boiling Point: °C | | | | |
| Sample Wt 20 mg | 1.5 | Refractive Index, no | | | | |
| Picatinny Arsenal Apparatus, in. Sample Wt, mg | 13 17 | n ₂₅ | | | | |
| Time trying II | | no | | | | |
| Friction Pandulurs Test: | | Vacuum Stability Test: | | | | |
| Steel Shoe | | cc/40 H·s, at | | | | |
| Fiber Shoe | | 6. C | | | | |
| Rifle Bullet Impact Test: Trials | | 100°C | | 0.2 | | |
| % | | 120°C | | 0.5 | | |
| Explosions | | 135°C | | | | |
| Partials 60 | | 150°C | | | | |
| Burned 40 | | 200 Grem Bomb Sand Test | : | | | |
| Unaffected 0 | | Sand, gm | | 48.5 | | |
| Explosion Temperature: "C | | Sensitivity to Initiation: | _ | | | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Cl | harge, gm | | | |
| 1 5 December 220 | | Mercury Fulminate | | 0.26* | | |
| 5 Decomposes 320 | | Lead Azide | | 0.24* | | |
| 10 15 | | Tetryi *Alternative initiati | ng charges. | | | |
| 20 | | Ballistic Morter, % TNT: | (a) | 112 | | |
| | | Frouzi Test, % TNT: | (t) | 101 | | |
| 75°C Internetional Heat Test: % Loss in 48 Hrs | 0.05 | Plate Dent Test: | (c) | | | |
| 70 Loss III 40 Firs | 0.0, | Method | | Α | | |
| 100°C Heat Test: | | Condition | | Pressed | | |
| % Loss, 1st 48 Hrs | 0.03 | Confined | | No | | |
| % Loss, 2nd 48 Hrs | 0.09 | Density, gm/cc | | 1.50 | | |
| Explosion in 100 Hrs | Kone | Brisance, % TNT | | 107 | | |
| P | | Detonation Rate: | (a) | | | |
| Flammability Index: | | Confinement | | Unconfin ed | | |
| Hygroscopicity: % 30°C, 90% ldf |) ol | Condition | Pressed | Cas | | |
| пунгосорисну: № 30°С, 90% ВН | 0.04 | Charge Dameter, in. | .0 | 1.25 | | |
| Volatility: | | Density, gri/cc | 1.04 | 1.71 | | |
| | | Rate, meters/second | >270 | 7350 | | |

Picric Acid

| Booster Sensitivity Test: | | c) | Decomposition Equation: |
|--|---------|---------------------------|---|
| Condition | Pressed | Cast | Oxygen, atoms/sec (Z/sec) |
| Tetryl, gm | 10 | 5 | Heat, kilocalorie/mole |
| Wax, in. for 50% Detonation | | | (AH, kcal/mol) |
| Wax, gm | 2 | 0 | Temperature Range, "C |
| Density, gm/cc | 1.6 | 1.7 | Phase |
| Heat of: Combustion, cal/gm | 2 | .72 | Armor Plate Impact Test: |
| Explosion, cal/gm | 10 | 000 | 60 mm Mortor Projectile: |
| Gas Volume, cc/gm | | 675 | 50% Inert, Velocity, ft/sec |
| Formation, cal/gm | | 245 | Aluminum Fineness |
| Fusion, col/gm (a) Temperature, or | | 0.4 122 | 500-lb General Purpose Bombs: |
| Specific Heet: cal/gm/°C (e) | | | Disc. Third was to be |
| ° <u>c</u> | ٥ | .235 | Plate Thickness, inches |
| 30 | 0 | .258 | 1 |
| 30 60 | | . 282 | 114 |
| 90 120 | | . 310 . 337 | 11.2 |
| 100 | · | , ,,,, | _ 13, |
| Burning Rate: cm/sec | | | Somb Drop Test: |
| Thermal Conductivity: (f) cal/sec/cm/°C Density, gm/cc | 6.2½ x | 10 ⁻¹⁴ 1406 | 17, 2000-th Semi-Armor-Piercing Bomb vs Concrete: |
| Coefficient of Expansion: | | | Max Safe Drop, ft |
| Linear, %/°C | | | 500-lb General Purpose Bomb vs Concrete: |
| Volume, %/°C | | | Height, ft |
| Hardness, Mohs' Scale: | 2 | .1 | Trials |
| 115-Fuldes | ٤ | • • | Unaffected |
| Young's Modulus: | | | Low Order |
| E', dynes/cm² | | | High Order _ |
| E, Ib/inch² | | | ,,,,,,, |
| Density, gm/cc | | | 1000-lb General Purpose Bomb vs Concrete: |
| | | | Height, ft |
| Compressive Strength: Ib/inch ² | | | Trials |
| | | | Unaffected |
| Vapor Pressure: | | | Low Order |
| °C mm Mercu | ry | | High Order |
| 195 2 | | | |
| 255 50 | | | |
| | | | |

Picric Acid

| Fragmentation Test: | Shepad Charge Effectiveness, TNT = 100 |): | | | |
|---|---|---------|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, lb | Glass Cones Steel Cones Hole Volume Hole Depth | | | | |
| Total No. of Fragments: For TNT | Color: Yell | ov | | | |
| For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb | Principal Uses: Formerly projectile filler, now explosive admixture; and for the manufac are of Explosive D | | | | |
| Total No. of Fragments: For TNT For Subject HE | Method of Loading: Pro | ssed | | | |
| Progress Velocity: ft/sec At 9 ft At 25½ ft Density, gm/cc | Louding Density: gm/cc psi x 3 5 10 12 15 1.40 1.50 1.57 1.59 1.6 Storage: | 20 | | | |
| Blest (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 | | | |
| Air: Peak Pressure Impulse Energy Air, Confined: | Compatibility Group Exudation | Group I | | | |
| Impulse Under Weter: Peok Pressure Impulse Energy Underground: Peok Pressure Impulse Energy | | | | | |

Pierie Acid

| <u>olubi</u>] | ity: grame | per 100 | grems (%) | of: (g) | | | | | |
|----------------------------------|---|----------------------|----------------------|-------------------|--|--------------------------|------------------|----------------------|--------------------------|
| 3 | ater | Alc | cohol | <u>Be</u> | nzene | <u>T</u> | oluene | Eth | er |
| <u>°c</u> | ž | °c | \$ | <u>°c</u> | ٤ | °c | ž | <u>°с</u> | ž |
| 0 20 40 60 80 100 | 0.85 1.17 1.88 2.98 4.53 7.1 | 0 20 40 | 1.9 5.9 12.0 | 20 40 60 | ~2 9.6 27.5 59 | 20 60 | ~13 ~30 | 20 34•7 | ~3 3.96 |
| Chlo | roform | Ethyl | acetate | | bon chloride | Pyz | dine | Acet | one |
| °c | ž | °c | ž | °c | £ | °c | 2 | <u>°c</u> | <u> </u> |
| 20 60 | ~6 ~6 | 20 30 40 50 | 42 50 58 69 | 20 60 | ~0.07 ~0.4 | 10 30 50 | 24 37·5 58 | 20 30 40 50 | 125 137 164 208 |
| M | ethanol | Isop | ropyl elec | hol | Propano | 1-1 | Carbon d | isulfide | |
| <u>°c</u> | £ | °c | | ž | <u>°c</u> | 2 | <u>°c</u> | 2 | |
| 0 20 40 50 | 14 19 31 41 | 10 30 50 | | 6.4 9.8 5.5 | 0 20 40 50 | 2.4 3.3 5.4 7.4 | 20 30 | 0.12 0.16 | |
| | tion: (Sum | | | | | | | | |
| | 6 + Hg(NO ₃) ₂ | | | | - | _ | | (| 1) |
| | 5mem3 + m21 | | | | - | (NO3)5 | | (| 2) |
| с6н | 5140 + 2140 - | | | | C6H5N2NO3 | | | (| 3 a) |
| CEH | 5N2NO3 + H20 | · —— | | | C ₆ H ₅ OH + N | s + HMO3 | | (| 3 b) |
| | 50H + HNO3 | | | | | + н ⁵ 0 | | | 3c) |
| с6н | 5 ^{NO} öxidati | on and | NO3 rearrangem | ent | SNC ⁶ H ⁷ OH | | | (| 4) |
| o ^S M | с6сн + ни о3 | | 102 | | (0 ₂ N) ₂ C6H ₃ | он + н20 | | | 5) |
| | и) ₂ с6н ³ он + | | | | | | | (| 6) |

Picric Acid

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The two variables of greatest importance in this process are nitric acid concentration and the effective concentration of benzene (i.e., benzene dissolved in the expnitration solution). The optimal concentration of nitric acid is in the range 10.4 to 11.6 molar (or the equivalent of 50% to 55% by weight for pure acid). The acid concentration greatly influences the over all rate of reaction, below 10.4 molar the rate falls off rapidly, while above 10.4 molar the rates of both the expnitration reaction and various side reactions, such as direct nitration, increase rapidly. The range mentioned above seems, in general, to give the lowest proportion of neutral nitro-compounds to nitro-phenols with, at the same time, an adequate rate of expnitration. The expnitration solution must be fortified frequently, or, preferably, continuously with nitric acid. Strengths of nitric acid between 95% and 98% are best, due to the smaller increase in reaction volume than if weaker acid were used. The use of absolute nitric acid requires that its direct contact with liquid benzene be avoided.

The effective concentration of bearene is probably the most critical variable affecting the proportion of neutral nitro-compounds to nitrophenols and amounts of colored by-products. Saturation of the exymitration solution with bearene is undesirable and thus in batch processes slow bearene addition is preferable to the addition of it in one portion; in continuous processes where an excess of bearene is used the rate of agitation is important.

The concentration of mercuric nitrate catalyst does not appear to be a critical factor over a mainly wide range. Concentrations of 0.3% to 0.5 mole of mercuric nitrate per liter of oxymitratio, solution have been found to give satisfactory results in most cases.

A continuous process, known as the continuous addation process, works on the following cycle. The oxynitration solution is saturated with bendene by vigorous agitation with excess benzene at more temperature, the saturated solution is separated from excess benzene and direculated through a heated coil; it is then cooled to room temperature and agitat i again, with benzene, which extracts the organic product and resaturates the oxynitration solution. In evaluating this process, the rate of formation of dinitrophenol per liter of reacting solution in the coil is determined; To gm of dinitrophenol per liter per hour is representative performance. The dinitrophenol is, of course, nitrated to picric acid.

Origin:

Picric Acid was first prepared in 1771 by Woulff who found the reaction of nitric acid and indigo yielded a dye. Hausmarn isolated Picri Ar i in 1776 and studyed it further (Journal de physique 32, 165 (1780)). The proparation was studied by many chemists but in 1841 Laurent established its identity (Ann chim this III, 2, 221 (1841)). It was used as a yellow dye until Purpin, in 1865, proposed Picric of as a pursting charge for high explosive shell (French Potent 187,512). The British adopted disric Acid as a military explosive in 1868 under the mane of lyddite and other nations soon began to use it as the first melt-loaded high explosive. Mixtures of other explosives and Picric Acid were developed until it was gradually replaced by TMT about 1900. Today Pic ic Acid is used for the manufacture of Explosive D.

Destruction by Chemical Lecompositions

Pieric Acid is decomposed by dissolving in 25 times its weight of a solution made from 1 part sodium hydroxide and 21 parts sodium sulfide (Naph 9HgO) in 200 parts of water. Some hydrogen sulfide and ammonis are evolved.

References: 60

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Mircellaneous Sensitivity Tests; Performanc: Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) Ph. Naoum, Z ges Schiess-Sprengstoffw, pp. 181, 229, 267 (27 June 1932).
 - (c) D. P. MacDougall, Methods of Fnysical Testing, OSRD Report No. 803, 11 August 1942.
- (d) G. H. Masserly, The Rate of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
 - (e) International Critical Tables.
- (f) E. Hutchinson, The Thermal Sensitiveness of Emplosives. The Thermal Conductivity Emplosive Materials, AC Report No. 2861, First Report, August 1942.
 - (g) Values taken from various sources in the open literature.
 - (h) Also see the following Picatinny Arsenal Technical Reports on Picric Acid:

| <u>ī</u> | 2 | 3 | 4 | 2 | <u>6</u> | 1 | 8 | 2 |
|----------|------------------------------------|------|-------------------|-------------------|---|--------------|------|------|
| 1651 | 132 582 1172 1352 1372 | 1363 | 694 764 874 | 65 425 1585 | 266 556 926 976 986 1446 1556 | 1347 1557 | 1118 | 15.9 |

⁶⁰See Cootnote 1, page 10.

| Composition: | | Molacular Weight: | 310 |
|---|------------|--------------------------------|-------------|
| ~ | | Oxygen Salence: | |
| PEIN | 81 | CO: % | -74 |
| A.3.4. A = A.17 | • • | CO % | -31 |
| Gulf Crown E 011 | 19 | Doneity: gm/cc Hend tampe | 1.35 |
| | | Melting Point: *C | |
| C/H Ratio | | Freezing Point: *C | |
| Impact Sonitivity, 2 Kg Wt: | | Boiling Point: *C | |
| Bureou of Mines Apparatus, (Sample Wt 20 mg | cm | Refrective Index, no | - |
| Picatinny Arsenal Apparatus, | , in. 11 | T | |
| Sample Wt, mg | 27 | n <u>e</u> | |
| Friction Pendulum Test: | | Vocuum Stability Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| Fiber Shoe | Unaffected | 90°C | |
| | | — 100°C | 0.48 |
| Rifle Bullet Impact Test: Tr | ials | 120°C 16 hours | 11+ |
| | % | 135°C | _ |
| | 0 | 150°C | , |
| | Ç. | | |
| | 0 | 200 Grcm Bomb Sond Test: | |
| Unaffricted 10 | 0 | Sand, gm | 41.6 |
| Explosion Temperature: | ·c | Sonsitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, g | m |
| 1 | | Mercury Fulminate | 0.20* |
| 5 Decomposes* | | Lead Azide | 0.20* |
| 10 | | | |
| 15 | | *Alternative initiating char | rges. |
| 20 *No value obtained. | | Ballistic Morter, % THT: | |
| 75°C International Heat Test: | | Treuzi Test, % TNT: | |
| % Loss in 48 Hrs | | Plate Dent Test: (a) Method | В |
| 1001C Mark Tari | | Condition | Hand tamped |
| 100°C Heat Test: | | Canfined | No No |
| % Loss, 1st 48 Hrs | 0.17 | Density, gm/cc | |
| % Loss, 2nd 48 Hrs | 0.00 | 1 | 1.33 |
| Explosion in 100 Hrs | None | Brisance, % TNT | 76 |
| Flommobility Index: | | — Detaration Rate: Confinement | None |
| | | - Condition | Hand tamped |
| Hygrescepicity: % 30°C, 90 | % RH 0.02 | | 1.0 |
| | , | Charge Diameter, in. | |
| Volatility: | | Density, gm/cc | 1.37 |
| V COUNTRIEV: | | Rate, meters/second | 7075 |

| Fragmentation Test: | | Shaped Charge Effectivaness, TNT = 100: |
|---|----------------|--|
| 90 mm HE, M71 Projectile, Let WG- | 91: | Glass Cones Steel Cones |
| Density, ym/cc | 1.33 | Hole Volume |
| Charge Wt, Ib | 1.723 | Hole Depth |
| Total No. of Fragments: | | Color: |
| For TNT | 703 | Catal: |
| For Subject HE | 519 | Principal Uses: Plastic demolition explosive |
| 3 Inch HE, M42A1 Projectile, Let KC | .\$: | |
| Density, gm/cc | 1.39 | j |
| Charge Wt, Ib | 0.735 | |
| Total No. of Fragments: | | Method of Londing: Hand tamped |
| For TNT | 514 | |
| For Subject HE | 428 | Leading Density: gm/\ta 1.35 |
| Fragment Velocity: ft/sec At 9 ft | | Leeding Density: gm/cc 1.35 |
| At 251/2 ft | | Storage: |
| Density, gm/cc | | Mathod Dry |
| Blast (Relative to TNT): | | Hazard Class (Quantity-Distance) Class 9 |
| Air: Peak Pressure | | Compatibility Group Group I |
| Impulse | | Exudation |
| Energy | | |
| Air, Coofined: Impulse | | Origin: PIPE, a mechanical mixture of PETN and Gulf Crown E Oil, was developed in the United State during World War II. |
| Under Water: Pagk Pressure | | |
| Impulse | | References: 61 |
| Energy | | (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III-Miscellaneous |
| Underground: Peak Pressure | | Sensitivity Tests; Perfor ance Tests, OSRI Report No. 5746, 27 December 1945. |
| Impulse | | (b) S. Livingston, Properties of Explosive RIPE, PIPE and PEP-3, Picatinny Arsenal Techni |
| Energy | | cal Report 1517, 24 April 1945. |
| Preparation: | | 1 |
| PIPE is manufactured by simp mixing of PETN in oil. | ole mechanical | |

⁶¹See footnote 1, page 10.

Plumbatol

| Composition: % | | Molocular Weight: | 291 |
|---|----------|----------------------------------|---------------------------------------|
| | | Oxygen Belence: | |
| Lead Nitrate | 70 | CO ₂ % | -5.4 |
| INT | 30 | | +9.3 |
| | | Density: gm/cc Melting Point: *C | · · · · · · · · · · · · · · · · · · · |
| C/H Ratio | | Freezing Point: *C | |
| | | | |
| mpact Semitivity, 2 Kg Wt. Bureau of Mines Apparatus, cm | | Boiling Point: *C | |
| Sample Wt 20 mg | 13 | Refractive Index, no | |
| Picatiwny Arsenal Apparatus, in. Sample Wt, mg | 13 22 | ng | |
| | | n ₅ | |
| Friction Pondulus: Test: | | Vocuum Stability Test: | |
| Steel Shoe | | cc/40 Hrs, at | |
| Fiber Shoe | | 90°C | |
| Riffe Bullet Impact Test: Trials | | 100°C | |
| • | | 120°C | |
| % Explosions | | 135°C | |
| Portials | | 150°C | |
| Burned | | 200 Grem Bomb Sand Test: | |
| Unaffected | | Sand, gm | 32.4 |
| Explosion Temperature: 'C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) | | Minimum Detonating Charge, gm | |
| 1 | | Mercury Fulminate | |
| 5 Decomposes 238 | | Lead Azide | 0.20 |
| 10 15 | | Tetryi | 0.^0 |
| 20 | | Bellistic Morter, % TNT: | |
| | | Trouzi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | | Plate Dent Test: Method | |
| 00°C Heat Test: | | Condition | |
| % Loss, 1st 4B Hrs | | Confined | |
| % Loss, 2nd 48 Hrs | | Density, gm/cc | |
| Explosion in 100 Hrs | | Brisance, % TNT | |
| lemmebility Index: | | Detonation Rate: (b) | |
| | | Confinement | |
| Tygroscopicity: % | | Condition | |
| | | Charge Diameter, in. | |
| /olatility: | | Density, gm/cc | 2.39 |
| | | Rate, meters/second | 4350 |

Plumbatol

| fragmentation Test: | Shoped Charge Effectiveness, TNT = 100: |
|--|--|
| 90 mm HE, MT? Projectile, Let WC-91: Density, gm/cc Charge Wt, lb | Glass Cones Steel Cones (a) Hole Volume 11 ¹ Hole Depth 103 |
| Total Me, of Progments: For TNT For Subject MF | Color: Light yellow |
| 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Utana |
| Total No. of Fragments: For TNT For Subject HE | Mathrd of Loading: Cast |
| Pregment Velocity: ft/sec | Leading Density: gm/cc |
| At 9 ft At 251/4 ft Density, gm/cc | Storage: Method Dry |
| Bleet (Relative to TNT): | Hazard Class (Quantity-Distance) Class 9 |
| Air: Peak Pressure Impulse Energy | Compatibility Group Group I |
| Air, Confined: Impulse Under Weter: | Origin: An explosive containing 70% lead nitrate and 50% TNT has been used in Belgium under the name of "Marcarite." |
| Peak Pressure Impulse Energy | References: 62 (a) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation Cavity Effect with Explosive Composition, MI |
| Undergreund: Pook Pressure Impulse Energy | (b)es Dictionary of Applied Chemistry. Fourth Edition, Vol IV, Longmans, Greand Company, London - New York - Toronto, p. 464. |
| Preparation: Plumbatol is manufactured by simple mechanical mixing of lead nitrate in molten TWT. | |

⁶²See footnote i, page 10.

PLX (Liquid)

| Composition: | | | Melocular Weight: | 100 61 | 25/5 |
|---|-------------|-----------------------|----------------------------|---------------------|-------------|
| % | 100 | * | Oxygen Belence: | 91 | 91 |
| Ni trome thene | 100 | 95 | CO ₂ % | -39 | -48 |
| Ethylenediamine | /- | 5 | CO % | -13 | -21 |
| *The mixture 95/5 Niti is designated PLX (for sive). See note under | or Piceting | y Liquid Explo- | Density: gm/cc | 1.14 | 1.12 |
| arvey. See noor und | or Scorage. | ' | Melting Foint: *C | -2 9 | |
| C/H Ratio | | | Freezing Point: °C | | |
| Impact Sanshivity, 2 Kg W Bureau of Mines Appara | | 100 95/5 100+ 100+ | Builing Point: "C | 101 | |
| Sample Wt 20 mg | - | | Refrective Index. no | | |
| Picatinny Arsenal Appar | ratus, in. | 20 20 | n o | | |
| Sample Wt, mg | | 20 20 | ng | | |
| Friction Fundalum Test: | | | Vocuum Stability Test: | | |
| Steel Shoe | Ur | affected | cc/40 Hrs, at | | |
| Fiber Shoe | Ur | affected | 90°C | | |
| | | | 100°C | | |
| Rifle Bullet Immeet Test: | LO Trials | 5 Trials | 120°C | | |
| | % | \$ | 135°C | | |
| Explosions | 0 | | 150°C | | |
| Partials | 0 | O | | | 05/5 |
| Burned | Ö | C/ | 200 Gram Bomb Sond Tool | . <u>100</u> 8.1 | <u>95/5</u> |
| Unaffected | 100 | 100 | Sand, gm | 8.1 | 50.6 |
| Explosion Temperature: | •c | °C | Sensitivity to Indition: | , | |
| Seconds, 0.1 | 100 | <u>95/5</u> | Minimum Detonoting C | harge, gm | |
| 1 | | | Mercury Fulminate | | |
| 5 | 430 | 430 | Lead Azide | | |
| 10 | | | Tetryl | | |
| 15 | | | | 3 al. | |
| 20 | | | Saffistic Morter, % TNT: | 134 | |
| 75°C International Heat To | | | Trougi Toot, % PA | 127 | |
| % Loss in 48 Hrs | | | Plate Dest Test: Method | | |
| 100°C Heat Test: | | | Condition | | |
| % Loss, 1st 48 Hrs | | | Confined | | |
| % Loss, 2nd 48 Hrs | | | Density, gm/cc | | |
| Explosion in 100 Hrs | | | Brisance, % TNT | | |
| | | | Detonation Rate: | 1/32"* | 1/32"* |
| Flommobility Index: | | | | Glass | Glass |
| | | | | Liquid | Liquid |
| Hygrescepicity: % | | | Charge Diameter, in. | 1.25 | 0.94 |
| | | | | 1.14 | 1.12 |
| Volatility: | | | 1 | 6 21C | 6165 |

PLX (Liquid)

| Beester Sensitivity Test: Kitromethane Condition | Decemposition Equation: (d) <u>Nitromethque</u> Oxygen, atoms/sec 10 ¹⁴ |
|--|---|
| Tetryl, gm | (Z/sec) Heat, kilocalarie/male 56.6 |
| Wax, In. for 50% Detonation | (AH, kcol/mol) |
| Wax, gm | Temperature Ronge, °C 380-430 |
| Density, gm/cc | Phose Geneous |
| Nest ef: (a) Combustion, col/gm 2630 | Armer Plata Impact Test: |
| Explosion, cat/gm | 40 mm Mortur Projectile: |
| Gas Volume, cc/gm | 50% Inert, Velocity, ft/sec |
| Formation, cal/gm -348 | Aluminum Fineness |
| Fusion, col/gm Vaporization, cal/gm 149 | 500-lb General Purpose Bembe: |
| Specific Heat: col/gm/°C (b) | Diana Thisteness tendens |
| C = 0.4209 ~ 0.00076t + 0.0000061t ² for 15°C to 70°C | Plate Thickness, inches |
| | 1 |
| | 11/4 |
| | 11/2 |
| | 1% |
| Burning Rate: cm/sec | |
| | Romb Drop Test: |
| Thermal Conductivity: cal/sec/cm/°C | 17, 2000-th Sami-Armor-Planting Bomb vs Contrate: |
| Coefficient of Expansion: | Max Safe Drop, ft |
| Linear, %/°C | 300-th General Propose Semb vs Concrete: |
| Volume, %/°C | Height, ft |
| | Trials |
| Mardness, Mohs' Scale: | Unaffected |
| Yanna'a Madahan | Low Order |
| Young's Medulus: | High Order |
| E', dynes/cm² E. lb/inch² | |
| Density, gm/cc | 1000-lb General Purpose Bomb vs Concrete: |
| | Height, ft |
| Compressive Strongth: Ib/inch ² | Trials |
| | Unaffectea |
| Vapor Pressura: (c) | Low Order |
| °C mm Mercury | High Order |
| 70 258 | |
| 85 ### | |
| | |

PLX (Liquid)

| Light yellow Light yellow ield clearing Pumping 100 95/5 1.14 1.12 as stored separately; y when ready to use Distonce) |
|---|
| Pumping 100 95/5 1.14 1.12 as stored separately; y when ready to use |
| Pumping 100 95/5 1.14 1.12 as stored separately; y when ready to use |
| 100 95/5 1.14 1.12 as stored separately; y when ready to use |
| 100 95/5 1.14 1.12 as stored separately; y when ready to use |
| 100 95/5 1.14 1.12 as stored separately; y when ready to use |
| 100 95/5 1.14 1.12 as stored separately; y when ready to use |
| 1.14 1.12 s stored separately; y when ready to use |
| 1.14 1.12 s stored separately; y when ready to use |
| s stored separately; y when ready to use |
| y when ready to use |
| y when ready to use |
| y when ready to use |
| -Distance) |
| |
| |
| |
| |
| |
| 100 95/5 0.5 0.063 |
| es: (<) |
| |
| 0.748 0.625 |
| 0.533 |
| |
| ild steel and duriron |
| s brass. |
| |
| |
| |
| |
| |

Origin:

Hitromethene has been known since 1872 (Kolbe, J prakt Chem (2) 5, 427 (1872), but was available only as a laboratory product until it appeared as an industrial chemical in 1940. A number of patents have been issued for nitromethene produced as a by-product of the citration of propens (U. S. Patent 1,967,667 (1934); British Patent 3,707 (1937); and Canadian Patent 371,007 (1938).

The development of nitromethane liquid explosives was based on information that nitromethane is sensitized to initiation and propagation of deconation by the addition of various emines. This study made at Picatinny Arsenal in 1945 indicated that mixtures of nitromethane with 5% of ethylenediamine, n-butyl-amine, or morpholine ghowed considerable promise for application in mine-field clearance (L. H. Eriksen and J. W. Rowen. PATR No. 1965, 17 September 1945).

References:63

- (a) D. E. Holcomb and C. F. Dorsey, "Thermodynamic Properties of Nitropareffine," Ind Eng. Chem 41, 2788 (1949).
- (b) J. W. Williams, "A Study of the Physical Properties of Nitromethane," J Am Chem Soc 47, 2644 (1925).
 - (c) L. Medard, "Explosive Properties of Nitromethane," Mem poudr 33, 125 (1951).
- (d) T. L. Cottrell, T. E. Graham and T. J. Heid, "The Thermal Decomposition of Mitramethanes," Transactions of the Faraday Society 47, 584 (1951).
- (e) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes and W. C. Bill, "Chemical Propellants: Stability of Monomitromethane," Ind Engr Chem 40, 1320 (1948).
 - (f) Also see the following Picatinny Arsenal Technical Reports on Nitromethane:

| <u>o</u> | 1 | . 3 | 5 ` | <u>6</u> | 1 | <u>8</u> | 2 |
|----------|--------------|------|------------|----------|------|----------|------|
| 1660 | 1681 1831 | 2113 | 1565 - | 2016 | 1747 | 1708 | 1619 |

⁶³See footnote 1, page 10.

Potassium Dinitrobensfurozan (KDRBF)

| Co. yposition: | Weleanler Meight: (KCEHFHFOE) | 225 |
|---|--|------------|
| ** NO2 | Oxygen Belence: CO ₂ % CO % | -60 -18 |
| 0 36.3 C2N NO K | Density: gm/cc | 2.21 |
| к 14.8 | Melting Point: *C Explodes | 510 |
| C/H Ratio 0.416 | Presning Point: *C | |
| Supert Sensitivity, 2 Kg Wt: Bureou of Mines Apparetus, cm | Solding Point: *C | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3; (1 1b wt) 6 Sample Wt, mg | Refrective Index, no no no no | |
| Frietico Pendulum Test: | Yacuum Stubility Toot: | |
| Steel Shoe Explodes | cc/40 Hrs, at | |
| Fiber Shoe Explodes | 90°C | |
| Riffle Bullet Empact Test: Trials | 120°C | |
| % | 135°C | |
| Explosions | 150°C | |
| Portiols | | |
| Burned Unaffected | 200 Green Bench Send Test: Sand, gm 44.8 Black poster fine 9.5 | 43.6 |
| Exploiten Temperature: "C | Squaltivity to Initiation: | |
| Seconds, 0.1 (no cop used) | Minimum Detariating Charge, gm | |
| | Mercury Fulminate 0.30 | 0.20 |
| 5 250 10 | Lead Axide | 0.10 |
| 1. (1. (1. (1. (1. (1. (1. (1. (1. (1. (| Tetryl | |
| 20 | Sellistic Mortor, % TMT: | |
| | Trausi Yest, % THT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Seet Test: Method | |
| 100°C Heat Test: | Condition | |
| % Loss, 1st 48 Hes 0.03 | Confined | |
| % Loss, 2nd 48 Hrs 0.05 | Density, gm/cc | |
| Explosion in 100 Hrs Hone | Brisance, % TNT | |
| Floremebility Index: | Determent Confinement | |
| Mygressepicity: % 30°C, 75% RH 0.11 30°C, 90% PH 0.27 | Condition Charge Dierseter, in. | |
| V:/atility: | Density, gm/cc | |
| · | Rate, misters/second | |

Potassium Dinitrobensfuroman (XDMBF)

| December Semaltivity Tests | | Decemposition Equation: |
|--|----------------|--|
| Condition | | Onygen, etome/sec |
| Tetryl, gm | ٠, | (Z/sec) Heat, kilocolorie/mole |
| Wax, in. for 50% Detonation | | (AH, kcol/mol) |
| West, gm | | Tomperature Range, *C |
| Density, gm/cc | | Phase |
| Mont of: | 2209 | Armer Plate Impest Test: |
| Combustion, col/gm | | • |
| Explosion, cal/gm | 725 604 | 60 mm Morter Projectile: |
| Gas Volume, cc/gm | 004 | 50% Inert, Velocity, ft/sec |
| Formation, col/gm | | Aluminum Fineness |
| Fusion, cal/gm | N.S. | 500-th General Purpose Bembe: |
| Specific Meet: col/gm/°C (b) | | |
| <u>°c</u> | 125,7 | Plate Thickness, inches |
| | A 23.77 | |
| -50 0 | 0.217 0.217 | . 1 |
| 25 | 0.217 | 1% |
| 50 | 0.217 | 11/4 |
| | | - 1% |
| Burning Rate: cm/sec | | |
| On/ sac | | Somb Drop Test: |
| Thermal Canductivity: cal/sec/cm/°C | | 17, 2000-th Souni-Armor-Pleasing Bomb vs Concepte: |
| | | Max Safe Drap, ft |
| Coefficient of Expension: | | Max sale orap, it |
| Linear, %/°C | | 500-16 General Purpase Bomb vs Constate: |
| Volume, %/°C | | Height, ft |
| | | Triols |
| Mardness, Mahe' Scale: | | Unaffected |
| Manager A. A. A. A. A. | | Low Order |
| Young's Medulus: | | High Order |
| E', dynes/cm² | | 1 |
| E, Ib/inch ^a | | 1888-lb General Purpase Bumb vs Cancrete: |
| Density, gm/cc | | M. J. A. 40 |
| Compressive Strength: Ib/inch ² | | - Height, ft |
| Compression on outgoing 10/ IIII/ | | Triols |
| | | Unaffected |
| Vapor Pressure: mm Mercury | | Low Order |
| THIS MERCURY | | High Order |
| | | |
| | | |
| | | } |

Potassium Dinitrobenzfuroxan (KDNBF)

| · | | |
|--|--|-------------|
| 90 mm ME, M71 Projectile, Let WC-91: | Glass Cones Steel Cone | 15 |
| Density, gm/cc | Hole Volume | |
| Charge Wt, ib | Hole Depth | , |
| Total No. of Fragments: | Color: Orange t | o home |
| For TNT | Canal Canal | OTOWN |
| For Subject HE | Principal Uses: Primary ex | plosive |
| 2 Inch HE, M42A1 Projectile, Let KC-5: | | |
| Density, gm/cc | | |
| Charge Wt, Ib | | |
| Total No. of Fragments: | Method of Leading: Pres | sed |
| For TNT | | |
| For Subject HE | Leading Density: gm/cc psi x | |
| Fragment Valueity: ft/sec | 10 20 30 40 1.63 1.77 1.81 1.86 | 80 1.98 |
| At 9 ft | | |
| At 251/4 ft | Storage: | |
| Dersity, gm/cc | Method | Wet |
| Blook (Refetive to TNT): | Hazard Class (Quantity-Distance) | Class 9 |
| Air: | Compatibility Group Gr | oup M (web) |
| Peak Pressure | Exudation | |
| impulse | | |
| Energy | | |
| Air, Confined: | Solubility in Wat ., gm/100 gm solvent, at: | |
| Impulse | | |
| | 30°c | 0-245 |
| Under Weter: | Stab Sensitivity: | |
| Peak Pressure | Density Firing Point (inc | |
| . Impulse | gm/cc 0/5 50% | 100% |
| Energy | 1.63 73 79 1.77 66 75 | 84 |
| Underground: | 1.77 66 75 1.81 42 48 | 83 64 |
| Peak Pressure | 1.86 12 15 | 1.8 |
| Impulse | 1.93 11 17 | 21 |
| Energy | 1.98 7 11 | 14 |
| | Activation Energy: | |
| | kcai/mor | 82.6 |
| | Induction Period, see | 3.5-10 |

AMCP 706-177

Potassium Dinitrobenzfurowan (KDRBF)

Preparation of Potassium Salt of 4,6-dinitrobensfurozan: (a)

Benishrowan, made by the reaction of ortho-nitroaniline cast alkaline sodium hypochlorite, was discolved in 6 parts of 96% sulfuric acid and nitrated at 5° -20°C with a 4 to 1 sulfuric-nitric acid mixture. The salt was prepared by neutralization of the 4,6-dinitrobensfurousn with potassium bicarbonate followed by recrystallization from hot water. The product forms in small golden orange plates which explode at 210°C.

Origin:

The potassium salt of 4,6-dinitrobenzfuroxan was first prepared in 1899 by von P. Drost (Ann 307, 56 (1899)).

References: 64

- (a) R. J. Gaughran, J. P. Picard and J. V. R. Kaufman, "Catribution to the Chemistry of Bensfurous Derivatives," J Am Chem Soc 76, 2233 (1954).
- (b) C. Lenchitz, Ice Calorimeter Determination of Enthalpy and Specific Heat of Eleven Organometallic Compounds, PATR No. 2224, November 1955.
- (e) Also see the following Picatinny Arsenal Technical Reports on Potassium Dinitro-

<u>2</u> <u>3</u> <u>6</u> <u>9</u> 2 2.22 2093 2146 2179

⁶⁴See footnote 1, page 10.

| Composition: | | Moleculer Walght: | 252 | |
|---|------|--|----------------|--|
| RDX | 30 | Oxve "elence; | | |
| - | | 2.4 | -45 - 9 | |
| Tetryl | 50 | • Vensity: gm/cc | 1.68 | |
| TMT | 20 | Mel - Point: 'C Eutectic | 67 | |
| C/H Ratio | | Freezing Point: 'C | - • | |
| | | | | |
| Impest Sensitivity, 2 Kg Wt: Byveau of Mines Apparatus, cm | 111 | Beiling Point: *C | | |
| Sample Wt 20 mg Picationy Arsenal Apparatus, in. | | Refrective Index, na | | |
| Sample Wt, mg | | n <u>u</u> | | |
| - | | no no | | |
| Frietlen Pendulum Test: | | Vacuum Stability Test: | | |
| Steel Shoe | | cc/40 Hrs, at | | |
| Fiber Shoe | | 90°C | 3.0 | |
| Riffe Bullet Impact Test: Trials | | 120°C | 3.0 | |
| . % | | 135°C | | |
| Explosions 20 | | 150°C | ٤ | |
| Partials 20 | | | | |
| Burned 0 | | 200 Gram Bomb Sánd Test: | -1 0 | |
| Unaffected 60 | | Sand, gm | 54.8 | |
| Emplosion Temporature: *C | | Sensitivity to Initiation: | | |
| Seconds, 0.1 (no cop used) | | Minimum Detonating Charge; gm | 0.00* | |
| | | Mercury Fulminote | 0.23* 0.22* | |
| 10 | | Lead Azide | U. ZZ" | |
| 15 | | *Alternative initiating charges. | | |
| 20 | | Ballistic Morter, % TNT: (a) | 132 | |
| | | _ Trousi Test, % THT: | | |
| 75°C International Heat Test: % Loss in 48 Hrs | | Plate Don? Test: (b) | | |
| 2 COS #1 TO F #13 | | Method | В | |
| 100°C Heat Test: | | Condition | Cast | |
| | | Confined | No | |
| % Loss, 1st 48 Hrs | | Density, gm/cc | 1.68 | |
| % Loss, 1st 48 Hrs % Loss, 2nd 48 Hrs | | | | |
| | | Brisance, % TNT | 127 | |
| % Loss, 2nd 48 Hrs Explosion in 100 Hrs | | Detenation Rate: | | |
| % Loss, 2nd 48 Hrs | | Detenction Rate: Confinement | None. | |
| % Loss, 2nd 48 Hrs Explosion in 100 Hrs Planmability Index: | | - Detenation Rate: Confinement Condition | None. | |
| % Loss, 2nd 48 Hrs Explosion in 100 Hrs | 0.00 | Detenction Rate: Confinement | None. | |

| Fragmentation Test: | | Shoped Charge Effectiveness, TNT == | : 100: |
|---|-----------------|---|-------------------|
| 90 mm HE, M71 Projectile, Let WC-91: | | Glass Canes Stee | I Conss |
| Density, gm/cc | 1.64 | Hole Volume | |
| Charge Wt, Ib | 2.180 | Hole Depth | |
| Total No. of Fragments: | | Color: | |
| For TNT | 703 | | |
| For Subject HE | 999 | Principal Uses: Land mines and o | lemolition |
| 3 inch HE, M42A1 Projectile, Let KC-5: | | charges | |
| Density, gm/cc | 1.63 | | |
| Charge Wt, Ib | 0.864 | | |
| Total No. of Fragments: | | Method of Looding: | Cast |
| For TNT | 514 | | |
| For Subject HE | 685 | Landan Banku anda | 1.68 |
| Freement Velocity: ft/sec | | Leeding Density: gm/cc | 1.00 |
| At 9 ft At 25½ ft | 2690 2460 | Storage: | |
| Density, gm/cc | 1.64 | 1 | |
| | | Method | Dry |
| Blest (Relative to TNY): | | Hazard Class (Quantity-Distance) | Class 9 |
| Ain | (d) | Compatibility Group | Group I |
| Peak Pressure | 111 | 6 . 1.1 . | |
| Impulse | 109 | Exudation | Brudes at 65°C |
| Energy | | | |
| Air, Confined: | | Preparation: | |
| Impulse | | The ternary explosive system RDK, tetryl and TNT is prepare | |
| Under Weter: | | appropriate weight of water-we tol (40/60) previously melted | et RDK to a tetry |
| Peak Pressure | | jacketed melt kettle. Heating | |
| Impulse | | are continued until all the W | iter is evaporate |
| Energy | | and the mixture is uniform in PTX-1 is also prepared by addi | |
| Underpreund: Pack Pressure | | Composition B. | |
| Impulse | | Compatibility with Metals: | |
| Energy | | Dry: Aluminum, mild steel | not affected. |
| Booster Sensitivity Test: (c) | | Wet: Aluminum, mild steel | not effected. |
| Condition Pross | | | |
| Tetryl, gm 100 | | | |
| Wax, in. for 50% Detonation 1.9 Density, gm/cc 1.6 | 1.82 51 1.68 | 1 | |

Origin:

The possibility of employing ternary mixtures to obtain emplosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armor piercing high emplosive rounds (PATR No. 1311, 17 July 1943). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary emplosive mixtures suggested by the Russian fillers, a mixture consisting of REM/tetryl/TET, designated PTx-1 was developed which had emplosive and physical properties offering considerable advantage for military applications (PATR No. 1350, 27 October 1943; and 1379, 11 January 1944).

A PTX-3 composition, prepared by the addition of Haleite to 40/60 tetrytol, also offered promise but limited to applications where the charge would not be required to withstand storage at 65° C without equilation.

References: 65

- (a) L. C. Smith and E. G. Ryster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. (33, 11 Augur.: 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDE/Wax Mixtures as a Substitute for Tetryl in Boostars, NOL Memo 10,303, 15 June 1949.
- (a) W. R. Tomlinson, Jr., Blast Effects of Bomb Emplosives, PA Tech Div Lecture, 9 April 1948.
 - (e) Also see the following Picatinny Arsenal Technical Reports on PTX-1:

| <u>o</u> | 2 | 3 | <u>6</u> | I | 2 |
|----------|------|------|--------------|------|-------------------------------|
| 1530 | 1402 | 1623 | 1466 1506 | 1437 | 1379 14 2 9 1469 |

| Composition: | Melecular Weight: 244 243 |
|---|--|
| RIM 44 - 41 PEIN 26 - 26 | CO ₂ % -33 -36 CO % -3 - k |
| TMT 26 - 33 | Density: grn/cc 1.70 |
| 181 20 5 33 | Mailing Point: °C Butectic 75 |
| C/H Ratio | Freezing Point: *C |
| Impact Sandkirky, 2 Kg Wt: Bureou of Mines Apporatus, cm 35 | Builing Palat: *C |
| Bureau of Mines Apparatus, cm 35 Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | Refrective Index, no. no. no. |
| Frietien Fendulum Test: Steel Shoe Crackle Fiber Shoe | Vecuum Stability Test: cc/40 Hrs, at 90°C |
| Riffe Buillet Impact Test: Triols | 100°C 2.6 |
| 95 Explosions 60 | 120°C 11+ |
| - · | 150°C |
| Partials 0 Burned 0 | |
| Unaffected 40 | 200 Gram Bomb Sand Test: Sand, gm 56.9 |
| Explication Temperature: *C Seconds, 0.1 (no cop used) | Scooltivity to Initiation: Minimum Detonating Charge, gm |
| 1 | Mercury Fulminate 0-23 |
| 5 10 | Lead Azide 0.00 |
| 15 | Tetryl 0.00 |
| 20 | Bellistic Mortor, % TNT: (a) 138 |
| | Trougi Test, % TNT: |
| 75°C International Heat Test: 96 Loss in 48 Hrs | Plate Bent Test: (b) Method B |
| 100°C Heat Test: | Condition Cast |
| % Loss, 1st 48 Hrs | Confined No |
| | Density, gm/cc 1.71 |
| % Loss, 2nd 48 Hrs | Brisance, % TNT 141 |
| % Loss, 2nd 48 Hrs Explosion in 100 Hrs | |
| | Detenation Rate: Confinement None |
| Explosion in 100 Hrs Planmability Index: | Confinement None Condition Cast |
| Explosion in 100 Hrs | Confinement None Condition Cast |

| Fragmentation Test: | | Shaped Charge Effectiveness, TNT = 1 | 0 0: |
|---|------------------------|--|--------------------------------|
| 90 mm HE, M71 Projectile, Let W | C-91: | Glass Cones Steel (| Cones |
| Density, gm/cc | 1.68 | Hole Volume ~ 130 | |
| Charge Wt, to | 2.226 | Hole Depth | · |
| Total No. of Fragments: | | Calor: | |
| For TNT | 703 | - | |
| For Subject HE | 1128 | Principal Uses: Shaped charges | |
| 3 Inch HE, M42A1 Projectile, Let N | (C-5: | Fragmentation ch | arges |
| Density, gm/cc | 1.70 | | |
| Charge Wt, Ib | 0.897 | | |
| Total No. of Fragments: | | Method of Localing: | Cast |
| For TINT | 514 | manage or concerns. | |
| For Subject HE | 750 | | |
| Construct Water to Annual Construction | | Leeding Density: gm/cc | 1.70 |
| Fregment Velocity: ft/sec At 9 ft At 25½ ft | 3020 2650 | Storege: | |
| Density, gm/cc | 1.70 | Method | Dry |
| Elast (Relative to THT): | | Hazard Class (Quantity-Distance) | Class 9 |
| Ain | (a) | Compatibility Group | Group I |
| Peak Pressure | 113 | Sunda ton | None at 65°C |
| Impulse | 113 | Excude rion | node at 0) t |
| Energy | *- | | |
| Ale, Confined: | | Preparation: | |
| Impulse | | The ternary explosive system RDX, PETN and TMT is prepared b | |
| Under Weter: Peak Pressure | | appropriate weight of water-wet tolite (30/70) previously melte | RDX to a pen- d in a steam- |
| Impulse | | jacketed melt kettle. Heating | and stirring |
| Energy | | are continued until all the wat and the mixture is uniform in c | omposition. |
| Underground: Pack Pressure | | PTX-2 is also prepared by addin PETN to RDX Composition 3. | g water-wet |
| impulse | | Compatibility with Metals: | |
| Energy | | Dry: Aluminum, mild steel n | ot affected. |
| Booster Sensitivity Test: | (c) | Wet: Aluminum not affected. | |
| Condition Tetryl, gm | Pressed Cast | | |
| Wax, in. for 50% Detonation Density, gm/cc | 1.87 2.32 1.70 1.61 | | |

Origin:

The possibility of employing ternary mixtures to obtain explosives having greater power and higher brisance than binary mixtures was suggested by the analysis of Russian 76 mm, armorpherein; high explosive rounds (PATR Ho. 1311, 17 July 1543). The Russian type ternary explosives, based on the composition and laboratory studies of such mixtures, were indicated to be effective pressed fillers. In conducting a preliminary study of castable ternary explosive mixtures suggested by the Russian fillers, a mixture consisting of RDM/PETM/DET, designated PTK-2 was developed which had explosive and physical properties offering considerable advantage for military applications (PATR Ho. 1360, 27 October 1943; and 1379, 11 January 1944).

A PTX-4 composition, prepared by the addition of Haleite to 30/70 Pentolite, also offered provide but because of border-line stability in accelerated stability tests, PTX-4 must be proven by long term storage to be acceptable for use in standard ammunition.

References: 66

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Explosives, Part III Miscellaneous Sensitivity Tests; Performance Tests, ORD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSED Report No. 803, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDE/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Merco 10,303, 15 June 1949.
- (d) W. R. Tomlinson, Jr., Blast Effects of Bomb Explosives, FA Tech Div Lecture, 9 April 1948.
 - (e) Also see the following Picatinny Arsenal Technical Reports on PTX-2:

| <u>o</u> | 2 | 3 | <u>4</u> | 2 | <u> 6</u> | <u>8</u> | 2 |
|----------|------|--------------|----------|------|-----------|----------|----------------------|
| 1530 | 1482 | 1483 1623 | 1414 | 1445 | 1466 | 1838 | 1379 1429 146) |

66See footnote 1, page 10.

| Composition: | | Meleculer Weight: | 21.7 |
|--|------------|--|------------|
| | | Oxygen Belonce: | |
| ROX | 90 | CO ₂ % | -37 -10 |
| Polywinyl Acetate | 8 | ∞ % | |
| Dibutylphthalate | 5 | Denotity: gm/cc Pressed | 1.60 |
| | | Sartaning Point; oc | 98 |
| C/H Retio | | Freezing Point: *C | |
| mpost Sensitivity, 2 Kg Wt: | | Boiling Point: *C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | 39 | Refractive Index, no | |
| Picatinny Arsenal Apparatus, in. | 9 | | |
| Sample Wt, mg | 13 | n <u>a</u> | |
| | | n _o | |
| frietlen Pendulum Test: Steel Shoe | Crackles | Vectors Stebility Test: | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | |
| FIDEN 3708 | | 100°C | 0.45 |
| Rifle Bullet Impact Test: 5Trick * | | 120°C | 0.88 |
| Explosions 20 | | 135°C | |
| | | 150°C | 11+ |
| Partials 0 Biumed 60 | | and Company Country Co | |
| | | 200 Gram Bomb Sand Test: Sand, gm | 58.5 |
| *IOO trials at -46°C - Uneffect | ted | | ,, |
| Explosion Temperature: *C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detanating Charge, gm | |
| 1 330 5 Decomposes 375 | | Mercury Fulminate | 0.22 |
| 10 265 | | Lead Azide | V. 22 |
| 15 | | Tetryl | |
| 20 | | Ballistic Mortor, % TNT: | |
| | | Trousi Test, % TNT: | |
| 75°C laternetional Heat Test: % Loss in 48 Hrs | | Plate Dent Test: Method | |
| 10016 Hard Tools | | Condition | |
| 100°C Heat Test: | 0.10 | Confined | |
| % Loss, 1st 48 Hrs | 0.16 | Density, grn/cc | |
| % Loss, 2nd 48 Hrs Explosion in 100 Hrs | - | Brisance, % TNT | |
| Explosion in 100 ins | None | - Detenation Rate: | |
| Flommobility Index: | | Confinement | None |
| | | Condition | Cas+ |
| Hygrescepicity: % 30°C, 90≸ RH | 0.20 | Charge Diameter, in. | 1.0 |
| | | Density, gm/cc | 1.60 |
| Veletility: 55°C, vacuo, 6 hrs | | | |

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 100; | | |
|--|--|-------------|--|
| 90 min HE, M71 Projectile, Let WG-91: Danelty, gm/cc Charge W1, Ib | Glass Cones Steel C Hole Volume Hole Depth | iones | |
| Total No. of Fragments: For TNT | Color: | White | |
| For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib | Principal Uses: Demolit | ion charges | |
| Total No. of Fragments: For TNT | Method of Looding: Pressed or extrud | | |
| For Subject HE | Looding Density: gm/cc | 1.60 | |
| Programm Velocity: ft/sec At 9 ft At 25½ ft | Storage: | | |
| Density, gm/cc | Method | Dry | |
| Sleet (Relative to THT): | Hazard Class (Quantity-Distance) | Class 9 | |
| Air: Paak Presure Impulse Energy | Compatibility Group Exudation No. | Group I | |
| Air, Confined: Impulse Under Weter: Pack Pressure | Plasticity: -40°C 25°C | Cracked | |
| Impulse Energy | | | |
| Undergrand: Peak Pressure Impulse Energy | | | |

Preparation:

Explosive PVA-4, a semi-plastic composition of Canadian origin, consists of 90% RDX, 8% polyvinyl acetate and 2% dibutylphthalate (DEP). This formulation was developed by Rr. Suthurland of Shawinigan Chemicals, Ltd. In evaluating various types of polyvinyl acetate commercially available in the United States, a type obtained from Union Carbide and Carbon, under the industrial named or designation "AYAT" was the most promising coating for RDX in the proportions RDX/FVA(AYAT)/DEP 92/6/2.

A practical method of preparing this composition was by the addition of a solution of the coating agent to an aqueous RDK slurry. Based on the quality of the product and the pellet densities obtained, a procedure of adding an acctone solution of PVA + DBP to a hot water slurry of RDK, under agitation, was adopted as standard.

References: 67

(a) See the following Picatinny Arsenal Technical Reports on PVA-4: 1532 and 1634.

⁶⁷See footnote 1, page 10.

| the control of the co | · ~ · · · · · · · · · · · · · · · · · · | |
|--|--|-------------------|
| Composition: | Molecular Weight: (C2H3MC3) n | (89) _n |
| C 27 | Oxygen Beleace: Cu., % CO % | -45 - 9 |
| H 3.4 (H ₂ C-CH-OHO ₂) _n | Density: gm/cc | |
| 0 54 | Making Point: *C (Soft Pb) | 50 |
| C/H Ratio 0.203 | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: 14.86/M | Boiling Point: *C | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | Refrective Index, no. no. no. no. | |
| Friction Fundation Test: Steel Shor Crackles Fiber Shoe Unaffected | Vector Stability Test: cc/40 Hrs, at 90°C | |
| Riffie Belligt Impact Yest: Tricks | 100°C 16 hours | 11+ 11+ |
| Explosions % | 135°C 150°C | * |
| Portiols Burned Unaffected | 200 Green Bomb Sand Test: Sand, gm | 49.9 |
| Explosion Temporatyre: °C Seconds, 0.1 (no cap used) 1 5 265 10 | Sensitivity to Initiation: Minimum Detanating Charge, gm Mercury Fulminate Lead Azide Tetryl | |
| 20 | Ballistic Morter, % TNT: | |
| | Treat Test, % THT: | |
| 75°C International Mont Yest: % Last in 48 Hrs | Plate Dent Test: Method | |
| 160°C Heat Test: % Loss, 1st 48 Hrs 1-9 | Condition Confined | |
| % Loss, 2nd 48 Hrs 2.1 | Density, gm/cc | |
| Explosion in 100 Hrs None | Brisance, % TNT | |
| Planmobility Index: | Detenation Rate: Confinement Condition | |
| HygrescepleBy: % 30°C, 90% RH 0.62 | Chr ge Diameter, in. | |
| Veletility: | Density, gm/cc Rate, meters/second | |

AMCP 706-177

PVM (Polyvinyl Mitrate)

| Progmontation Test: | Shoped Charge Officeltrezone, TMT == 100: | |
|--|---|----------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones | Į |
| Density, gm/cc | Hote Volume | - 1 |
| Charge Wt, ib | Hole Depth | 1 |
| Total No. of Fragments: | Colors | \dashv |
| For TNT | | ı |
| For Subject HE | Principal Vaso: | 7 |
| 3 Inch HE, MESAT Projectile, Let KC-5: | | 1 |
| . Density, gm/cc | • • | 1 |
| Charge Wt, th | | |
| Total No. of Progmosts: | Method of Leading: | \dashv |
| For TNT | | |
| For Subject HE | | |
| | Leeding Symby; gm/cc | ı |
| Programme Volumenty: Pt/sec | | |
| At 7 ft At 25½ ft | Sterage: | 7 |
| Density, gm/cc | | - (|
| · · · · · · · · · · · · · · · · · · · | . Method | - |
| Start (Salative to THT): | Hazard Class (Quantity-Distance) | |
| Alm | Competibility Group | 1 |
| Pook Pressure | | • |
| Impulse | Exudation | ļ |
| Energy | | - |
| Alt, Confined: | 65.5°C KI Test: | |
| longuitee | Minutes 60+ | |
| Under Waters | 134.5°C Heat Test: | |
| Pack Pressure | Selmon Pink 20 | i |
| Impulse | Red Punes 25 | |
| Energy | Explodes 300+ | |
| Undergreeund: | 240-Hour Hydrolysis Test: | |
| Peak Pressure | \$ HMO ₃ 5.07 | 1 |
| Impulse | Heat of: | 1 |
| Energy | | |
| | Combustion, cal/gm 2960 | |
| | Explosion, cal/gm 900 Gas Volume, cc/gm 836 | |
| • | 330 | |
| | | 1 |
| | · | |

PVN (Polyvinyl Nitrate)

Preparation:

Polywinyl alcohol is mixed with acetic anhydride. The mixture is cooled to -5° C and the nitric acid is added slowly while the mass is being stirr d. The temperature is controlled by the rate of acid addition so that when all the acid has been added the temperature does not rise above 20° C.

When the nitration is complete, the wixture is drowned by allowing a fine stream . The ayrupy liquid to flow from the nitrator and mix intimately with a large stream of water. This causes the product to precipitate in a fine state.

The finely divided precipitate is purified by boiling in frequent changes of water.

Origin:

The first preparation of polyvinyl nitrate was reported in 1929 by solution of polyvinyl alcohol in concentrated sulfuric acid and treatment with nitrating acid at a temperature not over 50°C. (German Patent 537,303). Later patents issued relative to polyvinyl nitrate included U. S. Patent 2,118,487 (1938) and German Patent 737,199 (1943).

| Composition: | Metecular Weight: 230 |
|--|---|
| % | mercener warpun: |
| | Oxygen Belence: |
| RDX 85 | CO, % -70 |
| Gulf Crown E Oil 15 | CO % -35 |
| • | Density: gm/cc Hand tamped 1-37 |
| | Molting Peint: *C |
| C/H Ratio | Freezing Point: *C |
| spect Sensitivity, 2 Kg Wt: | Boiling Polur: *C |
| Bureou of Mines Apparatus, cm 53 Sample Wt 20 mg | Refrective Index. nº |
| Picetinny Areenal Apparatus, in. 13 | - |
| Sample Wt, mg 25 | ο |
| | n <u>s</u> |
| Foliation Pandulum Test: | Vector Stebility Test: |
| Steel Shoe Unaffected | cc/40 Hrs, at |
| Fiber Shop. Unaffected. | 90°C |
| Date Date Investor | 100°C 0.34 |
| Riffe Pullet Impact Test: Trials | 120°C 0.56 |
| % | 135°C |
| Explosions 0 | 150°C |
| Partials 0 | |
| Burned 0 | 200 Gram Bomb Sand Test: |
| Unaffected 100 | Sand, gm 40-1 |
| Explosion Temperature: "C | Sonsitivity to Initiation: |
| Seconds, 0.1 (no cop used) | Minimum Detonating Charge, gm |
| 1 | Mercury Fulminate |
| 5 Decomposes; no value obtained | Lead Azide 0.20 |
| 10 | Tetryl |
| 15 | Sollistic Morter, % TNT: (a) 118 |
| 20 | Treast Test, % TNT: |
| 75°G International Heat Test: | Plate Door Test: (b) |
| % Loss in 48 Hrs | Method B |
| | _ |
| 160°C Heat Test: | Condition Hand tamped |
| % Loss, 1st 48 Hrs 0.03 | Confined No |
| % Loss, 2nd 48 Hrs | Density, gcn/cc 1.37 |
| Explosion in 100 Hrs None | Brisance, % TNT 85 |
| Planmability Index: | Detenation Rate: |
| remaining libers: | Confinement None |
| | Condition Hand tamped |
| | * · · · · · · · · · · · · · · · · · · · |
| Hygrseespickly: % 30°C, 90% RH 0.04 | Charge Diarneter, in. 1.0 |
| Figgracespicity: % 30°C, 90% RH 0.04 Velocities: | * · · · · · · · · · · · · · · · · · · · |

| | ~ ~~~ | | | |
|--|-------------------|---|--|--|
| Fragesagtation Test: | Market Service | Shapet Charge Effective | enecs. TNT == 100: | - |
| 90 mm HE, M71 Foojectits, Lot WC | :-91: | Glass (| Cones Steal Cone | • • |
| Density, gm/cc | 1.36 | Hole Volume | | |
| Chasss W !b | 1.786 | Hote Depth | | |
| | 1.4 | | 4.2 24 | |
| Total Ma. of Fragments: | | | | *** |
| For TNT | 703 | Color: | | White |
| For Subject PIE | 592 | | * * * | |
| LOL Winders ME | | Principal Uses: Plat | tic demolition | explosive |
| 3 treb HE MAZAT Projectile, Lat K | C-S: | | | |
| Density grovec | 1.42 | .0 | | |
| Charge Wt, Ib | 0.756 | | | |
| A CONTRACTOR OF THE CONTRACTOR | The second second | | | |
| Total No. of Fragmetter | | Shathad of Landler- | Hand ta | |
| For TN | 514 | Mathed of Looding: | Nang Ca | |
| For Subject ME | 501 | | | |
| on surport the | | Leading Density: gm/c | : | 1.37 |
| | | | - | |
| Fragment Velocity: ft/sec | 2650 | | | |
| At 9 ft At 251/4 ft | 2650 2370 | Storage: | | |
| Density, gm/cc | 1.395 | _ | | |
| | - 47.7 | Method | | Dry |
| | | | ala. Olasan 1 | Class 9 |
| Bleet (Reletive to TNT): | | Hazard Class (Quan | rity-Lastonce | 7 |
| A4 | | Compatibility Group | | Group I |
| Air: Peok Pressure | | | at 85°C in 30 | hre |
| Impulse | | Enudation None | at 95°C in 48 | hrs |
| Energy | | Equ | les at 105°C in | 48 hrs |
| er angy | | | | |
| Air, Confined: | | Origin: | | |
| Impulse | | RIPE, a mechanic | al mixture of RI | X and Gulf |
| | | Crown E Oil, was de | eveloped in the | United State |
| 14- A W-A | | during World War I | Į. | |
| Under Weter: | | l | | |
| Peak Pressure | | References | | |
| Peak Pressure Impulse | | (a) L. C. Smith | and E. G. Eyste | r, Physical |
| Peak Pressure | | (a) L. C. Smith Testing of Explosi | ves, Pert III - | Miscellaneou |
| Peak Pressure Impulse Energy | | (a) L. C. Smith Testing of Explosi Sensitivity Tests; | ves, Part III - Performance Tea | Miscellaneou |
| Peak Pressure Impulse Energy Underground: | | (a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. 746, 27 | ves, Pert III - Performance Tes December 1945. | Miscellaneou its, OSRD Re- |
| Peak Pressure Impulse Energy Underground: Peak Pressure | | (a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. *746, 27 | ves, Part III - Performance Tes December 1945. ugall, Methods o | Miscelleneousts, OSRD Re- |
| Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | | (a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. 746, 27 | ves, Part III - Performance Tes December 1945. ugall, Methods o | Miscelleneousts, OSRD Re- |
| Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy | | (a) L. C. Smith Testing of Explosi Sensitivity Tests; port No. **Ab, 27 (t) D. P. MacDo Testing, OSRD Repo (c) Also see th | Performance Tee Performance Tee December 1945. ugail, Methods ort No. 303, 11 A e following Pice | Miscellaneou its, OSRD Re- of Physical august 1942. |
| Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Preparation: | | (a) L. C. Smith Testing of Emplosi Sensitivity Tests; port No. *746, 27 | Performance Tee Performance Tee December 1945. ugail, Methods ort No. 303, 11 A e following Pice | Miscellaneou its, OSRD Re- of Physical august 1942. |
| Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy | imple mechanical | (a) L. C. Smith Testing of Explosi Sensitivity Tests; port No. **Ab, 27 (t) D. P. MacDo Testing, OSRD Repo (c) Also see th | Performance Tee Performance Tee December 1945. ugail, Methods ort No. 303, 11 A e following Pice | Miscellaneou its, OSRD Re- of Physical august 1942. |

68See footnote 1, page 10.

Silver Azide

| Composition: | Melecular Weight: (AgN ₃) 150 | |
|--|--|----|
| и 28.0 | Cxygen Belence: | |
| | CO ₂ % -5 | |
| Ag 72.0 | CO % -5 | |
| Ag-N=N = N | Density: gm/cc Crystal 5.1 | |
| | Melting Point: "C (a) 251 Decomposes rapidly above melting point to | |
| C/H Ratio | Freezing Point: "C silver and nitrog | en |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 6 | Boiling Point: 'C | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 3 | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. 3 Sample Wt, mg 18 | n ⊆ | |
| | n _s | |
| Friction Pendulum Test: PA Small Apparetus | Vacuum Stability Test: | |
| Steel Shoe Detonates | cc/40 Hrs, at | |
| Fiber Shoe Detonates | 90°C | |
| Rifle Beilet Impect Test: Trials | 100°C | |
| % | 120°C | |
| Explosions | 135°C | |
| Portials | 150°C | |
| Burned | 200 Gram Bomb Sand Test: | |
| Unoffected | Sand. am (b) | |
| | | _ |
| Explacion Temperature: 'C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) 310 | Minimum Detonaring Charge, gm | |
| 5 Emplodes 290 | Mercury Fulminate | |
| 10 | Leod Azide | |
| | Tetryl | |
| 15 20 | Ballistic Morter, % TNT: | _ |
| | Treuzi Test, % Hg(ONC) ₂ (c) 88 | _ |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Deat Test: Method | |
| 100°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs | Confined | |
| % Loss, 2nd 48 Hrs | Density, gm/cc | |
| Explosion in 100 Hrs | Brisance, % TNT | _ |
| Flammability Index: | Detenation Rate: Confinement | |
| | Condition | |
| Hygrescepicity: % (b) 25°C, 100% RH 0.04 | Charge Diameter, in. | |
| 2 | Density, gm/cc | |
| Voletility: 75°C, 24 hrs 0.00 | Rate, meters/second | |

Silver Azide

| Fragmentation Test: | Shaped Charge Effectiver see, TNT == 100: | | |
|--|--|---------------------|--|
| 90 mm HE, M71 Projectile, Let WG-91: | Glass Cones Steel | Cones | |
| Density, gm/cc | Hole Volume | | |
| Charge Wt, Ib | Hole Depth | | |
| Total No. of Fragments: | Color: Whit | e to gray | |
| For TNT | Comp. | e co gray | |
| For Subject HE | Principal Uses: In | itiators | |
| 3 insh HE, M42A1 Projectile, Let KC-S: | | 1 412 401 2 | |
| Density, gm/cc | | | |
| Charge Wt, Ib | İ | | |
| Total No. of Fragments: For TNT | Method of Leeding: Presso. | | |
| For Subject HE | | | |
| | Louding Density: gm/cc Var | iable | |
| Fragment Velocity: ft/sec At 9 ft At 2514 ft | Storege: | | |
| Dennity, gm/cc | | | |
| | Method | Wet | |
| Plant (Relative to TPTY): | Hazard Class (Quantity-Distance) | Class 9 | |
| Aire | Compatibility Group | M que a) | |
| Peak Pressure | | ••• | |
| Impulse | Exudation | None | |
| Energy | | | |
| Air, Confined: | Initiating Efficiency: | | |
| impulse | Grams Required to Give Complete Initiation of TNT | (e) 0.02-0.05 | |
| Under Weter: | Solubility in 100 gm Solvent | | |
| Peak Pressure | at Room Temperature: | | |
| Impulse Success | Solvent | Grams | |
| Energy | Water (b) | 0.006 | |
| Undergreund: | Ammonium hydroxide | Soluble | |
| Peak Pressure | Nitric acid Ether (b) | Decomposes 0.017 | |
| Impulse | Eth. 1 alcohol, 95% | 0.006 | |
| Energy | Acetone | 0.015 | |
| Explosive Power: (f) | Unaffected by water and CO2. | (a) | |
| Kilogram meters 192,000 | Heat of: | | |
| % Mercury Fulminate 1.097 | Explosion, cal/gm (c, a) | 452 | |

Silver Azide

Preparation;

MaN₃ + AgNO₃ → AgN₃ + MaNO₃

Prepare the following aqueous solutions:

- . a. 5% NaNg, sodium azide, 50 cc
 - b. 25% AgMO3, silver nitrate, 25 cc

The silver nitrate solution is placed in a 200 cc conductive rubber beaker equipped with a hard wood stirrer operated by an air motor. The sodium axide solution is placed in a separatory funnel fastened in a ring stand above the beaker containing the silver nitrate. A long cord (10 ft) is restened to the stopcock of the separatory funnel so that the funnel can be expited by remote control. The silver nitrate solution is now stirred very repidly and the sodium axide is slowly run into the nitrate solution. Stirring is continued for 5 minutes. The contents of the beaker are filtered through folded filter paper and vashed free of sodium axide and silver nitrate with distilled water.

Silver aside should be stored under water in a conductive rubber container. This preparation will yield approximately 7 grams.

The preparation should be conducted under a hood and behind a barricade. The product obtained by the above procedure has a very fine particle size, almost colloidal. Very fine silver axide is safer to handle and is just as efficient and stable as the large, coarse crystalline material (Ref b). When a thin film of fine silver axide is precipitated on mercury fulminate, tetryl, etc., these substances are as efficient weight for weight as pure silver axide (Ref g). White silver axide is less affected by light than mercury or lead axide (Ref h). Long colorless crystals which explode on breaking are obtained from associum hydroxide.

Origin:

Silver azide was first prepared in 1890-1 by T. Curtius (Ber 23, 3032; Ber 24, 3344-5) by passing hydrazoic acid (EMg) into neutral silver nitrate solution. Taylor and Rinkenbach prepared pure "collodial" aggregates and showed its sensitivity depends upon its particle size (Army Ordnance 5, 824 (1925). Silver azide was found in a detonator of foreign ammunition for the first time in 1945 (Ref 1).

References:65

- (a) A. R. Hitch, "Thermal Decomposition of Certain Inorganic Trinitrides," J Am Chem Soc 40, 1195 (1918).
- (b) C. A. Taylor and Wm. H. Rinkenbach, "Silver Azide: An Initiator of Detonation," Army Ordnance, Vol 5, p. 824 (1925).
 - (c) E. De W. S. Colver, High Employives, London and New York, p. 527.
 - (d) A. Stettbacher, Spreng u. Schlesstoffe, Rascher, Zurich, p. 97 (1948).
 - (e) A. Marshall, Explosives, 2nd Ed, Vol II, p. 767, London.
 - (f) A. Stettbacher, Z ges Schiess-Sprengstoffw 10, pp. 193-214 (1915).

⁶⁹See footnote 1, page 10.

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Silver Azide

- (g) F. Blechta, Chim et Ind Special No. 921-5 (June 1933); C. A. 28, 646.
- (h) L. Wohler and W. Krupko, Berichte 46, 2047-2050 (1913).
- (1) F. G. Haverlak, <u>Emandmention of 120/45 NM HE Shell</u>, Italian (FMAN-464), PATR No. 1515, 10 April 1945.

Tetracene

| Composition: | Melecular Weight: (C ₂ H ₆ N ₁₀ 0) 188 |
|--|---|
| % C 12.8 NH NH H 4.3 | Oxygen Belence: -60 CO % -43 |
| M 74.4 C-NH-NH-N = N-C | Density: gm/cc At 3000 psi 1.05 |
| o 8.5 NH 2 NH-NH-NO | Melting Point: °C Explodes 140-160 |
| C/H Ratio 0.068 | Freezing Point: *C |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm 7 | Belling Pelat: *C |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in.2; (8 oz vt) 8 Sample Wt, mg | Refrective Index, non non non non non non non non non no |
| Friction Pendulum Test: | Vocuum Stability Test: |
| Steel Shoe | cc/40 Hrs, at |
| Fiber Shoe | 90°C |
| Riffe Bullet Impact Test: Trials | 120°C |
| % | 135°C |
| Explosions | 150°C |
| Portiols Remark | |
| Burned Unaffected | 200 Green Bernb Send Test: Sond. om 28.0 |
| | Sond om 28.0 |
| Explosion Temperature: *C Seconds, 0.1 (no cop used) | Sensitivity to initiation: Minimum Detonating Charge, gm |
| 1 | Mercury Fulminate 0-40 |
| 5 160 | Lead Azide |
| 10 | Tetryi |
| 15 | D. West, AA. A. M. Thirt. |
| 20 | Balliatic Marter, % TNT: |
| TROP late motion of Manh Trans. | Trouzi Tost, % TNT: (a) 61 |
| 75°C International Heat Test: % Loss in 48 Hrs 0.5 | Plate Dent Test: Method |
| 100°C Heat Test: | Condition |
| % Loss, 1st 48 Hrs 23.2 | Confined |
| % Loss, 2nd 48 Hrs 3.4 | Density, gm/cc |
| Explosion in 100 Hrs None | Brisance, % TNT |
| Flormability Index: | Petenetien Rate: Confinement |
| Hygrescapicity: % 30°C, 90% RH 0.77 | Condition Charge Diameter, in. |
| Volatility: | Density, gm/cc Rate, meters/second |

| Gloss Cones olume spth Unes: Priming co detonators F Leeding: Closs (Quantity-Distr | Pale yellow mpositions and Pressed 1.05 |
|--|---|
| F Leeding: | Pressed 1.05 |
| View: Priming conditions detonators F Looding: Density: gm/cc 3000 psi | Pressed 1.05 |
| detonators F Leeding: Density: gm/cc 3000 psi | Pressed 1.05 |
| detonators F Leeding: Density: gm/cc 3000 psi | Pressed 1.05 |
| detonators F Leeding: Density: gm/cc 3000 psi | Pressed |
| detonators F Leeding: Density: gm/cc 3000 psi | Pressed |
| F Leeding: Density: gm/cc 3000 psi | Pressed 1.05 |
| Pensity: gm/cc 3000 psi | 1.05 Wet |
| Pensity: gm/cc 3000 psi | 1.05 Wet |
| Pensity: gm/cc 3000 psi | 1.05 Wet |
| Pensity: gm/cc 3000 psi | Wet |
| 3000 psi | Wet |
| 3000 psi | Wet |
| ı | Wet |
| | |
| | |
| | |
| Class (Quantity-Distr | once) Class 9 |
| | |
| tibility Group | Group M |
| | |
| ion | |
| | |
| ty: | |
| | 4 |
| | in water, alcohol, carbontetrachloride |
| | |
| ity to Electrosta | tic |
| | (b) |
| fined | 0.010 |
| ned | 0.012 |
| | |
| sion, cal/gm | 658 |
| | 1190 |
| ng Efficiency: | |
| | |
| cene is not effic | VIG 01118 |
| vient in the second sec | vity to Electrosta ge, Joules: onfined ined cosion, cal/gm as Volume, cc/gm cing Efficiency: racene is not effic pplosives. |

Tetracene

Preparation:

(Rinkenbach and Burton, Army Ordnance 12, 120 (1931)).

Tetracene is prepared by dissolving 5 gms of aminoguanidine dinitrate in 30 cc of water, cooling to 0°C and mixing with a solution of 2.5 gms of sodium nitrate in 15 cc of water. The temperature is maintained at about 10°C and 0.5 gm of acetic acid is added. The tetracene separates out and is washed with water, alcohol and ether. It is then dried.

Tetracene may also be prepared by placing aminoguanidine sulphate and sodium nitrite in a large beaker and adding water hered to 30°C. The heat of reaction causes the mixture to boil; after standing for two or three hours the separated tetracene is filtered off, washed thoroughly and dried.

Origin:

Tetracene was first prepared in 1910 by Hoffman and Roth (Ber 43, 682) who also studied its chemical reactions and determined its structure (Hoffman et al, Ber 43, 1087, 1866 (1910); Ber 44, 2496 (1911); and Ann 380, 131 (1911)). W. H. Rinkenbach and O. Burton made an extensive study of tetracene and described its manufacture and explosive properties (Army Ordnance 12, 120 (1931)).

Destruction by Chemical Decomposition:

Tetracene is decomposed by adding it to boiling water and continuing boiling for some time to insure complete decomposition.

References: 70

- (a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. G. Eyster, Physical Testing of Explosives. Part III Miscellaneous Sensitivity Tests; Performance Tests, OSRD Report No. 5746, 27 December 1945.
- (b) F. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
 - (c) Also see the following Picatinny Arsenal Technical Reports on Tetracene:

| <u>o</u> | 1 | <u>3</u> | <u>4</u> | 7 | <u>8</u> | 2 |
|----------|----|----------|--------------|-----|----------|----------------------|
| 1450 | 11 | 453 | 1104 2164 | 407 | 318 | 859 21 7 9 |

70See footnote 1, page 10.

Tetranitrocarbazole (TNC)

| Composition: | | Molecular Weight: (C ₁₂ H ₅ N ₅ O ₈) | 347 |
|--|-----------------|---|------------|
| % O ₂ N H N N N N N N N N N N N N N N N N N N | NO | Oxygen Belence: CO ₂ % CO % | -85 -30 |
| H 1.4 | No ₂ | Density: gm/cc | 4 |
| и 20.0 | • | Molting Point: °C Pure 1,3,6,8-is | omer 296 |
| 0 37.0 C/H Ratio 1.032 | | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | 100+ | Beiling Point: *C | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in: Sample Wt, mg | 18 | Refrective Index, no no no no no no no no no no no no no | |
| Friction Pendulum Test: | | Vecuum Stability Test: | |
| 3.30. 3.30 | Inaffected | cc/40 Hrs, at 90°C | |
| Fiber Shoe | Inaffected | 100°C | 0.2 |
| Rifle Bullet Impact Test: Trials | | 120°C | 0.2 |
| % 5 | | 135°C | |
| Explosions Partials | | 150°C | |
| Burned | | 200 Grem Bomb Sond Test: | |
| Unaffected | | Sand, gm | 41.3 |
| Explosion Temperature: 'C | | Sensitivity to Initiation: | |
| Secono: 0.1 (no cap used) | | Minimum Detonating Charge, gm Mercury Fulminate | |
| D. composes 470 | | Lead Azide | 0.20 |
| 10 | | Tetryl | 0.25 |
| 15 | | | |
| 20 | | Bellistic Morter, % TNT: | |
| 75°C International Heat Test: | | Trouxi Test, % TNT: | |
| % Loss in 48 Hrs | | Plate Dent Test: Method | |
| 190°C Heat Test: | | Condition | |
| % Loss, 1st 48 Hrs | 0.15 | Confined | |
| % Loss, 2nd 48 Hrs | 0.05 | Density, gm/cc | |
| Explosion in 100 Hrs | None | Brisance, % TNT | |
| Commobility Index: | | Detenation Rate: Confinement | • |
| Hygreecepicity: % 30°C, 90% RH | 0.01 | Condition Charge Diameter, in. | |
| | | Density, gm/cc | |

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Tetranitrocarbazole (TNC)

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = ' | TNT = 100: | |
|--|--------------------------------------|----------------------|--|
| 90 mm HE, M71 Projectile, Let WC-91: | Gicss Cones Steel | Cones | |
| Density, gm/cc | Hole Volume | | |
| Charge Wt, Ib | Hole Depth | | |
| Total No. of Fragments: | Color: Ld | ight yellow | |
| For TNT | , Cam. | Ruc Aerroa | |
| For Subject HE | Principal Uses: Component of ign | iter and | |
| 3 inch HE, M42A1 Projectile, Let KC-5: | pyrotechnic com | positions | |
| Density, gm/cc | | | |
| Charge Wt, Ib | | | |
| Total No. of Fragments: | Method of Leeding: | Pressed | |
| For TNT | mesical or covering: | Liesed | |
| For Subject HE | | | |
| | Leeding Density: gm/cc | | |
| Fragment Valuelty: ft/sec At 9 ft | • | | |
| At 251/4 ft | Storage: | | |
| Density, gm/cc | | | |
| | Method | Dry | |
| Staat (Relative to TNT): | Hazard Class (Quantity-Distance) | Class 9 | |
| Air: | Compatibility Group | | |
| Peak Pressure | • | | |
| Impulse | Exudation | | |
| Energy | | | |
| Air, Confined: | Solubility in Water, | | |
| Impulse | gm/100 gm (%), at: | | |
| | 95°C | 0.10 | |
| Under Weter: | / // | 0.20 | |
| Peak Pressure | Qualitative Solubilities: | | |
| Impulse | Solvent | Solubility | |
| Energy | | | |
| | Ni trobenzene | Very soluble | |
| Underground: | Acetone Benzene | Soluble Insoluble | |
| Peak Pressure | Chloroform | Insoluble | |
| Impulse | Carbontetrachloride | Insoluble | |
| Energy | Ether | Insoluble | |
| | Ether, petroleum | Insoluble | |
| | | | |
| | | | |
| | | | |
| | | | |

Tetranitrocarbasole (TNC)

Preparation:

Sulfonation: Fifty-six gms of carbazole is dissolved in 320 gms of H₂SO_L (96%, specific gravity 1.84). The solution is agitated during the addition of the carbazole and the temperature maintained at 25°-35°C. After the addition of the carbazole is completed, the agitation is continued and solution completed by raising the temperature to 80°-85°C and maintaining this temperature for one hour. The sulphate is now cooled to 20°C.

Mitration: The sulfonate solution is slowly added to 168 gms of HNO₃ (Plant grade specific gravity 1.525 at 15°C) saintaining the temperature at 30° to 50°C. (Time required - 1 hour 25 minutes). The temperature is then gradually raised to 70° to 75°C and maintained for one hour after which the temperature is raised to 85° to 90°C and held for one hour, then lowered to room temperature before drowning.

Drowning: The nitration mixture is drowned by pouring it into 2 to 3 volumes of ice and

Filtering: The separated light yellow product is filtered on a Buchner Funnel and washed with water twice to remove most of the acid.

<u>Purification:</u> The TMC is placed in hot water (95° to 100° c) and boiled for five to ten minutes with rapid agitation, allowed to settle then filtered and washed once. This procedure is repeated twice, making a total of three "boilings." The final wash is acid free.

Drying: The TNC is spread in a thin layer and dried at 100° to 110°C for four hours.

Yield: 73.3%.

Melting Point of TNC as prepared: 280°C (compares to 296°C for pure 1,3,6,8-isomer in preceding data).

Origin:

The preparation of Tetranitrocarbazole (TNC) was first reported in 1880 by C. Graebe (Ann 202, 26 (1880)) who nitrated carbazole with 94% nitric acid. Similar procedures were followed by R. Escales (Ber 37, 3596 (1904)) and P. Zierch (Ber 42, 3800 1909)). However, G. L. Clamician and P. P. Silber observed the formation of four isomeric TNC's when acetyl carbazole was treated with fuming nitric acid (Gazz chim ital 12, 272 1882). In 1912 and 1913 patents were issued to the dyestuff manufacturer, Casella and Company, covering the preparation of polynitrocarbazoles (German Patent 268,173 and French Patent 464,536). The Casella process of

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Tetranitrocarbazole (TNC)

preparing polynitrocarbazoles by dissolving carbazole in sulfuric acid and treating the solution of sulfonic acids with strong nitrating agents is essentially the process used today in the United States. The crude product, thus prepared, contains principally 1,3,6,8-TNC (W. Borsche and B. G. B. Scholten Ber 50, 596 (1917) and about 10% of the 1,2,6,8-TNC isomer (D. B. Murphy et al J Am Chem Soc 75, 4289 (1953). TNC was used in explosives by the Germans during World War II.

References: 71

- (a) D. B. Murphy, F. R. Schwartz, J. P. Picard and J. V. R. Kaufman, "Identification of Isomers Formed in the Nitration of Carbszole," J Am Chem Soc, 75, 4289-4291 (1953).
- (b) S. Livingston, Preparation of Tetranitrocarbazole, PA Chemical Research Laboratory Report No. 136, 330, 11 April 1951.
- (c) D. B. Murphy et al, Long Range Basic Technical R.search Leading to the Development of Improved Ignition Type Powders The Chemistry of Tetranitrocarbazole, PA Memorandum Report No. 22, 2 September 1952.
 - (d) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
 - (e) Also see the following Ficatinny Arsenal Technical Reports on Tetranitrocarbazole:

0 2 3 4 7 2180 1802 1973 1984 1647 1937

⁷¹See footnote 1, page 10.

2,4,2',4'-Tetranitro-oxanilide (TNO)

| Composition: | Molecular Weight: (C14H8N6O10) 420 | |
|--|--|--|
| % ° 40.0 ° . | Oxygen Belonce: | |
| Ī |) CO ₂ % -84 | |
| H 1.9 NH 人 WO | NH CO % -31 | |
| N 20.0 | NO ₂ Density: gm/cc | |
| 0 38.1 | Melting Point: °C Decomposes 313 | |
| C/H Ratio 0.735 | NC ₂ Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | Boiling Point: °C | |
| Sample Wt 20 mg | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. 30 Sample Wt, mg 11 | , | |
| and the straining and the stra | n _{so} | |
| Friction Fondulum Test: | Vocuum Stubility Test: | |
| Steel Shoe Unaffect | | |
| Fiber Shoe Unaffed | | |
| 810- 8-M-4 1 7 7 | 100°C | |
| Rifle Bullet Impact Test: Trials | 120°C 0-11 | |
| % Explosions | 135°C | |
| Partials | 150°C | |
| Burned | 200 Grum Bomb Sand Test: | |
| Unaffected | Sand, gm 16.3 | |
| Explosion Temperature: °C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) | Minimum Detonating Charge, gm | |
| | Mercury Fulminate | |
| 5 392 | Lead Azide 0.20 | |
| 10 15 | Tetryl 0.25 | |
| 20 | Bellistic Morter, % TNT: | |
| | Treuzi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plete Dent Test: Method | |
| 100°C Heat Test: | Condition | |
| | .07 Confined | |
| · | .00 Density, gm/cc | |
| | one Brisance, % TNT | |
| Explosion in rootins Inc | | |
| Flammability Index: | Detonation Rate: Confinement | |
| · | Condition | |
| Hygrescopicity: % 30°C, 90% RH Tr | Charge Diometer, in. | |
| | Density, gin/cc | |
| Veletility: | a control to the control of the cont | |

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2,4,2',4'-Tetranitro-omanilide (TNO)

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | |
|---|--|--|--|
| 90 man HE, M71 Projectile, Let WC-91; Eunsity, gm/cc Charge Wt, ib | Glass Cones Stept Cones Hole Volume Hole Depth | | |
| Total No. of Fragments: For TNT | Color: Light yellow | | |
| For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principel Uses: Component of black powder type and pyrotechnic compositions | | |
| Total No. of Fragments: For TN I' For Sub, act HE | Method of Loading: Pressed and extruded compositions | | |
| Fragment Velocity: ft/sec | Leading Density: gm/cc | | |
| At 9 ft At 25½ ft Density, gm/cc | Sterege: | | |
| Bleet (Relative to TNT): | Method Dry Hazard Class (Quantity-Distance) Class 9 | | |
| Air: Peck Prassure Impulse Energy | Compatibility Group Exudation | | |
| Air, Confined: Impulse | Solubility, gm/100 cc Solvent, in: | | |
| Under Weter: Peok Pressure Impulse | Water 100 <0.10 Nitrobenzene 150 >15 Qualitative Solubilities: | | |
| Energy Underground: Peoix Pressure Impulse Energy | Solvent Ethyl alcohol Benzene Butyl acetate Carbontetrachloride Ethyl ether Acetic acid Nitric acid Soluble Soluble Soluble Soluble | | |

Method of Preparation:

Omanilide:

Two parts of oxalic acid are mixed with one part of aniline in a round bottom flask. The mixture is stirred and heated until the reaction is complete as evidenced by the cessation of effervescence. The mass is cooled to room temperature, poured into several volumes of water (21°-24°C), filtered on a Büchner funnel and washed free of oxalic acid with water and then washed free of aniline with acetone. The oxanilide is air dried to remove the acetone and then dried at 100°-110°C.

Tetranitro-oxanilide (TNO):

A 5 liter round bottom flask is equipped with a stirrer of a type which wil? produce a accuracy "swirl." The flask is surrounded with a water jacket for hot and cold water. Fifteen hundred grams (1.5 kilograms) of 98% plant grade nitric acid is placed into the flask. Five hundred (500) grams of ommilide is slowly added to the acid under rapid agitation while the temperature is maintained below 10°C. After the addition of the ommilide is completed (2½-3 hrs), the agitation is continued 10-15 minutes. The temperature is then raised to 80°C over a period of one hour and maintained at 80°-85°C for 3 hours. The acid slurry is then cooled to room temperature and drowned by pouring over cracked ide. The product is filtered on a Büchner funnel and washed with water until it is almost acid free. The filter cake is placed in a beaker and sufficient water added to form a "slurry." Live steam is run into the "slurry" under agitation for 10 minutes. The slurry is filtered and the residue washed. The latter treatment of the "slurry" is repeated until the wash water is found to be neutral to

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2,4,2',4'-Tetranitro-oxanilide (TNO)

litmus paper. The TNO is washed with alcohol, then acetone, air dried and finally dried at 100° - 100° C.

Yield = 90% to 97.5% of theoretical.

Origin:

A. G. Perkin in 1892 obtained tetranitro-oxanilide directly by heating a solution of finely powdered oxanilide in nitric acid. He also obtained the same compound by the action of a cooled mixture of nitric and sulfuric acids on oxanilide and precipitating the product by pouring the solution into water (J Chem Soc 61, 460 (1892).

References: 72

- (a) S. Livingston, Development of Improved Ignition Type Powders, PATR No. 2267, July 1956.
- (b) D. Dubrow and J. Kristal, Substitution of Tetranitro Oxanilide and Hexanitro Oxanilide for Tetranitro Carbazole, PA Pyrotechnic Pessarch Laboratory Report 54-TF 1-88, 20 December 1954.

⁷²See footnote 1, page 10.

Tetryl

| Composition: | | Molecular Weight: (C7H5N508) | 287 |
|--|-------------------|--|-------------|
| C 29.3 H ₃ C- | N-NO ₂ | Oxygen Belence: CO ₂ % CO % | -147 - 8 |
| и 24.4 | 3 | Density: gm/cc Crysta | 1 1.73 |
| 0 44.6 | Y | Melting Point: *C | 130 |
| C/H Ratio 0.420 | NO ₂ | Freezing Point: *C | · |
| Impact Sensitivity, 2 Kg Wt: Bureau of Mines Apparatus, cm | 26 | Boiling Point: *C | |
| Sample Wt 20 mg Picotinny Arsenal Apparatus, in. Sample Wt, mg | 8 18 | Refrective Index, no no no no no no no no no no no no no | |
| Friction Pendulum Test: | | Vacuum Stability Test: | |
| Steel Shoe | Crackles | cc/40 Hrt. at | |
| Fiber Shoe | Unaffected | 90°C | •• |
| | | 100°C | 0.3 |
| Rifle Bullet Impact Test: Tric!s | | 120°C | 1.0 |
| % 5 | | 135°C | •• |
| Explosions 13 | | 150°C | 11+ |
| Partials 5 ¹ 4 | | | |
| Burned 10 | | 200 Grem Bomb Send Test: | _ |
| Unoffected 23 | | Sand, gm | 54.2 |
| Explosion Temperature: °C | | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) 344 | 0 | Minimum Detonating Charge, gr | n |
| 1 | | Mercury Fulminate | 0.20* |
| 5 Ignites 25 | | Lead Azide | 0.10* |
| 10 23 | | Tetwo | |
| 15 23 | | 1 | |
| 20 23 | 4 | Beilistic Morter, % TNT: (a) | 130 |
| 75°C International Heat Test: | | Trev.zi Test, % TNT: (b) | 125 |
| % Loss in 48 Hrs | 0.01 | Plate Deat Test: (c) | |
| | | Method A | В |
| 1001G Heat Test: | | Condition Pressed | Pressed |
| % Loss, 1st 48 Hrs | 0.1 | Confined Yes | No |
| % Lass, 2nd 48 Hrs | 0.0 | Density, gm/cc 1.50 | 1.59 1.36 |
| Explosion in 100 Hrs | None | Brisance, % TNT 116 | 115 96 |
| Flammability Index: | 544 | Detenation Rate: Confinement | None |
| Hygroscopicity: % 20°C, 90% RH | 0.04 | Condition | Pressed |
| | 0.04 | Charge Diameter, in. | 1.0 |
| Volatility: 25°C | 0.00 | Density, gm/cc | 1.71 |
| | 0.00 | Rate, meters/second | 7850 |

| Reaster Sensitivity Test: Condition | (d) Pressed | Decemposition Equation: Oxygen, atoms/sec | (g) 1015.4 (h) 1012.9 |
|--|----------------|---|-----------------------------|
| Tetryl, gm | 100 | (Z/sec) | 38.4 34.9 |
| Wax, in. for 50% Detonation | 2.01 | Heat, kilocalorie/mole (ΔΗ, kcal/mol) | JU14 J419 |
| Wax, gm | | Temperature Range, °C | 211-260 132-164 |
| Density, gm/cc | 1.58 | Phase | Liquid Liquid |
| Heat of: | | Armer Plate Impact Test: | |
| Combustion, cal/gm | 2925 | | |
| Explosion, cal/gm | 1080-1130 | 60 mm Mortor Projectile: | |
| Gas Volume, cz/gm | 760 | 50% Inert, Velocity, ft/ | sec |
| Formation, cal/gm | -14 | Aluminum Fineness | |
| Fusion, cal/gm o (e) Temperature, o | 22.2 127 | 500-lb General Purpose Be | mbe: |
| Specific Heat: cal/gm/*C | (e) | | |
| -1 00 | 0.182 | Plate Thickness, inches | |
| - 50 | 0.200 | 1 | |
| 0 | 0.212 | 194 | |
| 50 100 | 0.223 0.236 | 11/2 | |
| 100 | 0.230 | 13/4 | |
| Burning Rate: cm/sec | | - | |
| Thermal Conductivity: (f) col/sec/cm/*C 5.81 x 10_1, at 6.83 x 10 at | 1.394 gm/cc | T7, 2000-lb Semi-Armer-Pi | iorcing Bomb vs Concreto: |
| | 1.)20 gm/ ee | Max Safe Drop, ft | |
| Coefficient of Expension: Linear, %/°C | | 500-lb General Purposs de | omb vs Concrete: |
| Volume, %/°C | | Height, ft | |
| Mandage Mahal Roste | | Trials | |
| Herdness, Mohs' Scale: | | Unaffected | |
| Young's Modulus: | | Low Order | |
| E', dynes/cm² | | High Order | |
| E, lb/inch² | | 1000-lb General Purpose B | omb vs Concrete: |
| Density, gm/cc | | | |
| Companying Strength, Ib /ingl-7 | | Height, ft | |
| Compressive Strength: Ib/inch ² | | Trials | |
| | | Unaffectea | |
| Vapor Pressure: | | Low Order | |
| °C mm Mercury | | High Order | |
| | | | |

| 61 . | | | | | |
|---------------|---|--|--|---|--|
| .91 : | | Glass Con | es Steel (| Cones | |
| 1.58 | Hole Volu | me | | | |
| 2.052 | Hole Depti | h | | | |
| | Colon | | 71- | | |
| 703 | Color: | | rrg | ur Aerron | • |
| 864 | Principal Uni | Booster | er ingred | lent of e | |
| . -5 : | | sive mi | ixtures, d | | |
| 1.62 | | plasti | ig caps | | |
| 0.848 | | | | | |
| | Method of 1 | adlas. | | | |
| 514 | | reason. | | Free | seu |
| 605 | 1 - 1 | | | | |
| | Looding Deni | My: gm/cc | See to | elow | |
| | | | | | |
| | Storage: | | | | |
| | Method | | | Dr" | |
| | Hazard Cl | oss (Quantity- | Distance) | Clas | s 9 |
| | Compatibil | ity Group | | Grou | ıp L |
| | Exception | | Does not | evide at | 65 ³ C |
| | | | Does not | exude a | . 0, 0 |
| | Loading Den | sity: gm/c | ee | | |
| | | | | x 10 ³ | |
| | | | 10 12 | 15 | 20 |
| | 0.9 1.40 | 1.47 1 | 57 1.60 | 1.63 | |
| | İ | | 30 | | |
| | | 1 | | | |
| | Effect of T | emperature | on | (3) | |
| | | | | | |
| | | | -54 | 2 | L |
| | Density, | gm/cc | | | |
| | Rate, m/ | 8€ C | 7150 | 71 | 70 |
| | J | | | | |
| | | | | | |
| | 2.052 703 864 -5: 1.62 0.848 | 2.052 Hole Depth 703 864 Principal Use 2.5: 1.62 0.848 Method of Le Storage: Method Hazard Cli Compatibil Exudation Loading Den Cast 1. 0 3 0.9 1.40 Effect of T Rate of Det 16 hrs a Density, | 2.052 Hole Depth Color: 703 864 Frincipal Uses: Booster sive missive Color: Color: Color: Color: Itiginal Uses: Boosters; ingred sive mixtures, de blasting caps 1.62 0.848 Method of Loading: Loading Density: gm/cc See be Storage: Method Hazard Class (Quantity-Distance) Compatibility Group Exudation Does not Loading Density: gm/cc Cast 1.62 Pressed psi : 0 3 5 10 12 0.9 1.40 1.47 1.57 1.66 30 1.71 Effect of Temperature on Rate of Detonation: 16 hrs at, 0 -54 Density, gm/cc 1.55 | Color: Light yellow 864 Frincipal Uses: Boosters; ingredient of esive mixtures, detonstors blasting caps 1.62 0.848 Method of Leading: Pres Leading Density: gm/cc See below Sterage: Mathod Dr. Hazard Class (Quantity-Distance) Class Compatibility Group Group Exudation Does not exude at Loading Density: gm/cc Cast 1.62 Pressed psi x 10 ³ 0 3 5 10 12 15 0.9 1.40 1.47 1.57 1.60 1.63 30 1.71 Effect of Temperature on (1) Rate of Detonst.on: 16 hrs at, Oc -54 2 Density, gm/cc 1.52 1. |

Preparation:

(Manufacture of Tetryl by Dinitromonomethylaniline Process, Wannamaker Chemical Cc., Inc.)

$$c_{6}H_{3}(No_{2})_{2}c_{1} + c_{1}H_{2}H_{2} + NaOH \longrightarrow c_{6}H_{3}(No_{2})_{2}-NH-CH_{3} + NaCl + H_{2}O$$
 $c_{6}H_{3}(No_{2})_{2}-NH-CH_{3} + 2HNO_{3}$
 $o_{2}N$
 $H_{3}C-N-NO_{2}$
 $No_{2}N$
 $H_{2}C-N-NO_{2}$
 $No_{2}N$

To a solution of 202.5 gm dinitrochlorbenzene in 200 cc benzene, at 75°C with good sgitation, in 15 to 20 minutes, add 112 gm of 30% aqueous monomethylamine. Then add 129 gm of 31% aqueous sodium hydroxide, in 15 to 20 minutes, at such a rate as to cause refluxing; continue agitation for 3 hours at 70°C. The mixture is concentrated to a liquid temperature of 101°-102°C, cooled, filtered and the precipitate washed with distilled water until the washings give no test with silver nitrate, dried at 60°C (melting point 167.2°C)

The dinitromethylaniline is nitrated to tetryl by solution of it in 88% sulfuric acid (197 gm nitroaniline/1190 gm sulfuric) at 25°C, followed by addition of nitric acid. The process is carried out so that the water content remains at 16%. Solution (per 197 gm nitroaniline) requires 5 to 10 minutes, nitration, by addition of the sulfuric acid solution to nitric acid, about 1 hour at 30°C, plus 48 minutes at 50° to 55°C at the end. The mixture is then cooled to 20°C and filtered. The tetryl is dumped into 1 liter water, washed 2 or 3 times with 200 cc cold water, and then stirred 10 to 15 minutes at 50°C with 500 cc water, filtered warm and then washed with water until the washings are neutral to methyl orange. The tetryl dried to constant weight at 70°C weighs about 270 gm.

Tetryl filtered from an acid containing 87% sulfuric acid (or more) -13% water, at 40°C (or over) may fire in 30 minutes to 1 hour and 30 minutes, if not drowned in water. A safe nitration procedure, even on plant scale involves:

- 1. The concentration of sulfuric in the spent acid is maintained at a low level (approx 80/1.5/18.2 sulfuric/nitric/water).
 - 2. Nitration maximum temperature is 50°C.
 - 3. The slurry is cooled to $35^{\circ}\mathrm{C}$ before filtration.
 - 4. Filtration time prior to drowning, is minimized (15 minutes maximum).

The crude tetryl produced is recrystallized to remove impurit γ and occluded acid and to control its granulation.

Tetryl

Sensitivity of tetryl electrostatic discharge, joules; through 100 mesh: (i)

| Unconfined | 0.007 |
|------------|-------|
| Confined | 4.4 |

Solubility of tetryl, grams in 100 grams (%) of:

| <u>Ma</u> | ter | Carb | on tetrachl | ori de | Eth | ie". | 95% | Alcehol |
|----------------------------|---|---------------------|---------------|----------------------------------|---------------------|----------------------------------|---------------------------|---|
| °c | <u>\$</u> | °c | | <u> 15</u> | <u>°с</u> | 2 | <u>ос</u> | 2 |
| 0 20 40 30 100 | 0.0050 0.0075 0.0110 0.0810 0.184 | 6 20 40 60 | | 0.007 0.015 0.058 0.154 | 0 10 20 30 | 0.188 0.330 0.418 0.493 | 0 10 20 30 50 | 0.320 0.425 0.563 0.76 1.72 5.33 |
| <u>Chl</u> | oroforu L | Carbon d | isulfide £ | Ethyle °C | ene dichloride | <u> </u> | Acetone C | 2 |

| 0 20 40 60 | 0.28 0.39 1.20 2.65 | 0 10 20 30 | 0.009 0.015 0.021 0.030 | 25 75 | 4.5 45 | 30 40 50 | 75 95 116 1 3 8 |
|---------------------------------|--|---------------------|----------------------------------|----------------------|-----------------------------|----------------|---------------------------------|
| Trichloro | thylene | Ethyl | ace to te | Ber | zene | Polu | ene |
| <u>°c</u> | 2 | °c | 2 | <u>oc</u> | 2 | <u>°c</u> | <u> </u> |
| 0 20 40 60 80 86 | 0.07 0.12 0.26 0.67 1.50 1.76 | 20 | ~ 40 | 20 30 40 50 | 7.8 10.0 12.5 16.0 | 20 | 8.5 |

| <u>∆</u> `. | rene | 71 | A.T. |
|-------------|----------|-----------|------------|
| <u>°c</u> | <u> </u> | °c | 4 |
| 20 | 3-3 | 80 | ძ2 |
| 30 | 4.4 | 100 | 149 |
| 30 40 | 5.4 | 120 | 149 645 |
| 50 | 6.0 | | |

Origin:

Tetryl was first described in 1879 by Michler and Meyer (Ber 12, 1792), van Romburgh and Martens studied its properties and proved its structure (Rec trav chim 2, 108 (1883); 6, 215 (1887); and Ber 19, 2126 (1886)). Tetryl was not used as an explosive until World War I.

Destruction by Chemical Decomposition:

Tetryl is decomposed by dissolving in 12 times its weight of a solution prepared from 1 part by weight of sodium sulfite (Na₂SO₃·7H₂O) in 4 parts water. The sulfite solution may be heated to 80° C to facilitate decomposition of the Tetryl.

References: 73

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- (d) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303; 15 June 1949.
- (e) C. A. Taylor and Wm. H. Rinkenbach, "The Solubility of Trinitro-Phenylmethyl-Nitramine (Tetryl) in Organic Solvents," J Am Chem Sic 45, (1923) p. 104.
- (f) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC 2861, First Report, August 1942.
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- (h) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem 1090-1095 (June 1956).
- (i) J. W. Brown, D. H. Kusler and F. C. Gibson, Sensitivity of Explosives to Initiation by Electrostatic Discharges, U. S. Dept of Int, Bureau of Mines, RI 3852, 1946.
- (j) W. F. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR No. 2383, November 1956.
 - (k) Also see the following Picatinny Arsem 1 Technical Reports on Tetryl:

| 0 | 1 | <u>.5</u> | 3 | 4 | 5 | <u>6</u> | 7 | <u>.</u> | 9 |
|---|--|--|--|--|---|--|---|---|---|
| 30 600 770 810 1180 1290 1360 1400 1450 1500 1510 | 11 361 381 621 861 1041 1131 1261 1311 1431 1471 1611 | 132 582 832 882 1192 1352 1372 1402 1452 1592 | 453 493 623 863 1113 1373 2053 2163 2233 | 84 1294 1784 1784 1136 1264 1264 2004 | 65 195 1425 525 565 635 925 1145 1285 1405 1589 1935 2105 | 266 556 786 986 1086 1316 1376 1446 1466 1556 1636 | 117 197 637 707 807 837 1047 11437 1287 1337 1367 1437 1737 1737 1737 | 28 438 628 708 788 838 1418 1769 1828 1838 | 129 179 319 609 709 849 969 1029 1209 1429 1489 1819 1969 |
| | | | | | 2125 | | | | |

3see footnote 1, page 10.

Tetry to1, 80/20

| Oxygen Belonce: CO2 % CO % Density: gm/cc Cast Melting Point: "C Freezing Point: "C SoiHog Feint: "C | -52 -11 1.51 68 |
|--|--|
| CO % Density: gm/cc Cast Melting Point: *C Freezing Point: *C | -11 |
| Density: gm/cc Cast Melting Point: "C Freezing Point: "C | 1.51 |
| Melting Point: "C Freezing Point: "C | |
| Freezing Point: *C | 68 |
| | , |
| BeiHag Felat: "C | |
| | |
| Refrective Index, no | |
| n _s | |
| n ₂₀ | |
| Vocuum Stability Test: | |
| cc/40 Hrs, at | |
| 90°C | |
| — 100°C | 3.0 |
| 120°C | 11+ |
| 135°C | |
| 150°C | |
| 200 Gram Bomb Sand Test: | ······································ |
| Sand, gm | 54.0 |
| Sensitivity to Init(_vien: | |
| Minimum Detonating Charge, gm | |
| Mercury Fulminate | 0.22* |
| Leod Azide | 0.17* |
| *Alternative initiating charges. | |
| Bellistic Morter, % TNT: | |
| Trouzi Test, % TNT: | |
| Plate Dent Test: Method | |
| Condition | |
| Confined | |
| Density, gm/cc | |
| Brisance, % TNT | |
| Outonation Rate: | |
| | |
| | |
| | |
| | |
| | Vecuem Stability Test: cc/40 Hrs, at 90°C 100°C 120°C 135°C 150°C 200 Gram Bomb Sond Test: Sand, gm Sensitivity to Init(_*len: Minimum Detonating Charge, gm Mercury Fulminate Lead Axide *Alternative initiating charges. Bellistic Morter, % TNT: Trauxi Test, % TNT: Plate Dent Test: Method Condition Confined Density, gm/cc Brisance, % TNT |

Tetrytol, 80/20

| For TNT For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc Fragment Yelocity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Class 9 | regmentation Test: | Shaped Charge Effectiveners, TNT = 100: |
|--|--|---|
| Chorge Wt, Ib Total Na. of Frogments: For TNT For Subject HE 3 Inch HE, MAZA1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib **Vatal Na. of Frogments: For TNT For Subject HE Leading Density: gm/cc **Tregment Yelecity: ft/sec At 9 ft At 25½ ft Density, gm/cc **Method Dry Hozard Class (Quantity-Distance) Ale: Peack Pressure Impulse Energy Alir, Confined: Impulse Energy Under Water: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Energy Undergreend: Peack Pressure Impulse Impulse Energy | 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel Cones |
| Total Na. of Frogments: For TNT For Subject HE 3 Inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Tutel Na. of Frogments: For TNT For Subject HE Loading Density; gm/cc A1 9 ft A1 25/y ft Density, gm/cc Method Dry Blast (Relative to TNT): Air: Peack Pressure Impulse Energy AIr, Confined: Impulse Under Water: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Energy Underground: Peack Pressure Impulse Impulse | Density, gm/cc | Hole Volume |
| For TNT For Subject HE 3 lach HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib **Valuel No. of Fragments: For TNT For Subject HE Leading Density: gm/cc **Fragment Velocity: tr/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Air: Peak Pressure Impulse Energy Air, Coeffined: Impulse Under Water: Pack Pressure Impulse Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Energy | Charge Wt, Ib | Hole Depth |
| For TNT For Subject HE 3 lack HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, lb Tatel No. of Fragments: For TNT For Subject HE Looding Density: gm/cc Fragment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Blast (Relative to TNT): Air: Pack Pressure Impulse Energy Air, Confined: Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy Underground: Pack Pressure Impulse Energy | <u>-</u> | Color: Light yellow to buff |
| 3 leach HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, ib Total No. of Fragments: For TNT For Subject HE Leading Density: gm/cc Fragment Yelecity: tt/sec An 9 ft At 25½ ft Density, gm/cc Bleat (Reletive to TNT): Alar: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Energy Underground: Peak Pressure Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse Impulse | | |
| Density, gm/cc Charge Wt, Ib Total No. of Fregments: For TNT For Subject HE Loading Density: gm/cc Fregment Yelecity: ft/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Blast (Relative to TNT): Hoxard Class (Quantity-Distance) Class 9 Compatibility Group Group I Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy | For Subject HE | Principal Uses: Bursters, demolition blocks |
| Charge Wt, ib Tatel No. of Progments: For TNT For Subject HE Leading Density: gm/cc Fregment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Woter: Peak Pressure Impulse Energy Under Woter: Peak Pressure Impulse Impulse Energy Under Woter: Peak Pressure Impulse | 3 inch HE, M42A1 Projectile, Let KC-5: | |
| Total Ma. of Fragments: For TNT For Subject HE Loading Density: gm/cc Fragment Yelecity: tt/sec At 9 fr At 25½ ft Density, gm/cc Blast (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse | Density, gm/cc | |
| For TNT For Subject HE Leeding Density: gm/cc Fregment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Impulse Energy Air, Centined: Impulse Under Woter: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Energy Underground: Peak Pressure Impulse Impulse Energy | Charge Wt, Ib | · |
| For Subject HE Leading Density: gm/cc Fregment Yelecity: ft/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Blast (Relative to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | . = | Method of Looding: |
| Fregment Yelecity: tt/sec At 9 ft At 25½ ft Density, gm/cc Method Dry Method Dry Method Dry Method Dry Air: Peak Pressure Impulse Energy Air, Cenfined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | | |
| At 25½ ft Density, gm/cc Method Dry Bleet (Relative to TNT): Atr: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Underground: Impulse Underground: Impulse Impulse Underground: Peak Pressure Impulse | | Looding Density: gm/cc |
| Density, gm/cc Method Dry Blest (Relative to TNT): Air: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse Underground: Impulse Im | At 9 ft | • |
| Method Dry Blest (Reletive to TNT): Hazard Class (Quantity-Distance) Class 9 Air: Compatibility Group Group I Exudation Exudes at 65°C Air, Confined: Exudation Exudes at 65°C Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Impulse | | Storage: |
| Ale: Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse Energy | Density, gm/cc | Method Dry |
| Peak Pressure Impulse Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Exudation Exudes at 65°C Exudation Exudes at 65°C Under Water: Peak Pressure Impulse Energy | lest (Relative to TNY): | Hazard Class (Quantity-Distance) Class 9 |
| Impulse Exudation Exudes at 65°C Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | | Compatibility Group Group I |
| Energy Air, Confined: Impulse Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | | Sundation Provides at 6500 |
| Under Water: Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | • | Exaction Success to 05 C |
| Peak Pressure Impulse Energy Underground: Peak Pressure Impulse | | |
| Energy Underground: Peak Pressure Impulse | | |
| Underground: Peak Pressure Impulse | Impulse | Ì |
| Peak Pressure Impulse | Energy | |
| · · | | |
| Energy | Impulse | |
| | Energy | |
| | | |
| | • | |
| | | |

Te :rytol, 75/25

| Comporition: % | | Molecular Weight: | 270 |
|--|-------------|---------------------------------|---------------|
| Tetryl | 75 | Oxygen Belence: | |
| 70 0 i j | 12 | CO ₂ % CO % | -54 |
| INT | 2 5 | CO % | -12 |
| | | Density: gm/cc Cast | 1.59 |
| | | Melting Point: °C | 68 |
| C/H Ratio | | Freezing Point: "C | |
| mpest Sensitivity, 2 Kg Wt: | | Boiling Point: °C | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg | 28 | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. | 10 | 1 | |
| Sample Wt, mg | 17 | กต | |
| | | n | |
| riction Pendulum Test: | | Vocuum Stability Test: | |
| Steel Shoe C | racks | cc/40 Hrs, at | |
| Fiber Shoe U | naffected | 90°C | |
| Mile Bullet Impact Tests | | 100°C | 3.0 |
| Liffe Bullet Impact Test: Trials | | 120°C | 11+ |
| Explosions 0 | | 135°C | |
| Partials 30 | | 150°C | |
| Burned 0 | | 200 Gram Bomb Sand Test: | |
| Unaffected 70 | | Sand, am | 53.7 |
| | | | 73.1 |
| x; iesian Temperature: °C | | Sensitivity to Initiation: | |
| Ecronds, 0.1 (no cap used) | | Minimum Detonating Charge, gm | |
| i 5 Ignites 310 | | Mercury Fulminate | 0.23* |
| 10 | | Lead Azide | 0.19* |
| 15 | | *Alternative initiating charges | |
| 20 | | Bellistic Morter, % TNT: (a) | 122 |
| | | Transit Test, % TNT: | |
| 5°C International Heat Test: % Loss in 48 Hrs | | Plate Dent Test: (b) | |
| | | Method B | В |
| 00°C Heef Test: | | Condition Cast | Cast |
| % Loss, 1st 48 Hrs | | Confined No | Yen |
| % Loss, 2nd 48 Hrs | | Density, gm/cc 1.66 | 1.62 |
| Explosion in 100 Hrs | | Brisance, % TNT 118 | 114 |
| Inmobility Indon. 1933 | | Detonation Rate: | |
| lemmebility Index: Will not contin | nue to burn | Confinement | None |
| In an anicity of | 0.03 | Condition | Cast |
| lyyreacopicity: % | 0.03 | Charge Diameter, in. | 1.0 |
| feletility: | | Density, gm/cc | 1.60 |
| 7. | | Rate, meters/second | 7 3 85 |

Tetrytol, 75/25

| Fregmentation Test: | | Shaped Charge Effectiveness, TNT = | 100: |
|--------------------------------------|-------|---|---------------|
| 90 mm HE, M71 Projectile, Let WC-1 |)1: | Glass Cones Steel | Cones (d) |
| Density, gm/cc | 1.39 | Hole Volume 127 | |
| Charge Wt, Ib | 2.101 | Hole Depth 120 | |
| Total Ne. of Fragments: | | Color: Light vell | |
| For TNT | 703 | Light yell | low to buff |
| For Subject HE | 857 | Principal Uses: Bursters, demoli | tion blooks |
| 3 inch HE, M42A1 Projectile, Let KC- | 5: | | |
| Density, gm/cc | 1.60 | | |
| Charge Wt, ib | 0.845 | | |
| Total No. of Fragments: | | Method of Looding: | Cast |
| For TNT | 514 | | |
| For Subject HE | 591 | Leading Density: gm/cc | 1.59 |
| Fregment Velocity: ft/sec | · | | // |
| At 9 ft At 251/2 ft | , | Sterege: | ······· |
| Density, gm/cc | | Method | Dry |
| Hest (Relative to TNT): | | Hazard Class (Quantity-Distance) | Class 9 |
| Aire | X. | Compatibility Group | Group I |
| Peak Pressure | | Eurodosian | Exudes at 65° |
| Impulse | | Exudation | Exudes at 05 |
| Energy | | 2- | <u> </u> |
| Air, Confined: | | Eutectic Temperature, OC: | 67.5 |
| Impulse | | gr Tetryl/100 gm TNT 67.5°C | 54-82 |
| Under Weter: | | | • |
| Peak Pressure | | Booster Sensitivity Test: | (c) |
| Impulse Engage | | Condition | Cast |
| Energy | | Tetryl, gm | 100 |
| Underground: Pook Pressure | | Wax, in. for 50% Detonation Density, gm/cc | 1.65 1.66 |
| Impulse | | | |
| Energy | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Tetrytol, 70/30

| Composition: % | Melecular Weight: | 266 |
|--|----------------------------------|-------|
| Tetryl 70 | Oxygen Bolence: | |
| 14 11 10 | CO ₂ % | -55 |
| TNT 30 | CO % | -13 |
| | Density: gm/cc Cast | 1.60 |
| | Melting Point: *C | 68 |
| C/H Ratio | Freezing Point: *C | • |
| Impact Sazsitivity, 2 Kg Wt: Bureou of Mines Apparatus cm 28 | Boiling Point: *C | |
| Bureau of Mines Apparatus, cm 28 Sample Wt 20 mg | Refrective Index, no | |
| Picatinny Arsenal Apparatus, in. 11 | - | |
| Sample Wt, mg 18 | n _m | |
| | n ₉ | |
| Friction Pendulum Test: | Vecuum Stability Test: | |
| Steel Shoe Unaffected | cc/40 Hrs, at | |
| Fiber Shoe Unaffected | f | |
| Riffe Bullet Ir:pect Test: Trials | 100°C | 3.2 |
| • | 120°C | 11+ |
| % Exp!psions 0 | 135°C | |
| Partials 55 | 150°C | |
| Burned 0 | 200 Green Board Soud Toda | |
| Unaffected 45 | 200 Grem Bomb Send Text: | 53.2 |
| | Sand, gm | |
| Explosion Temperature: 'C | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cop used) 416 | Minimum Detonating Charge, gm | |
| l 387 5 Ignites 320 | Mercury Fulminate | 0.23* |
| | Leod Azide | 0.22* |
| | *Alternative initiating charges. | |
| 15 289 20 275 | Bellistic Merter, % TNT: (a) | 120 |
| | Trauzi Teet, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plete Dent Test: (b) | |
| 70 LASS III 90 F113 | Method | В |
| 100°C Heet Test: | Condition | Cast |
| % Loss, 1st 48 Hrs 0.1 | Confined | Yes |
| % Loss, 2nd 48 Hrs 0.1 | Density, gm/cc | 1.60 |
| , | n | 117 |
| Explosion in 100 Hrs None | | |
| Flammebility Index: Will not continue to b | Detenation Rate: Confinement | None |
| | | Cast |
| | | |
| Mygroscopicity: % 0.02 | Charge Dispetter in | |
| | | 1.60 |

Tetrytol, 70/30

| Fregmentation Test: | | Sheped Charge Effectiveness, TNT = 1 | 100: |
|---|--------|--|---------------|
| 90 mm HE, M71 Projectile, Lot W | /C-91: | Glass Canes Steel | Cones |
| Density, gm/cc | 1.60 | Hole Volume | |
| Charge Wt, Ib | 2.090 | Hole Depth | |
| Total No. of Fragments: | | Color: Light ye | llow to buff |
| For TNT | 703 | Coor: Mgnc ye | ITTOM CO CUIT |
| For Subject HE | 840 | Principel Uses: Bursters, demoli | tion blooks |
| 3 inch HE, M42A1 Projectile, Let | KC-5: | July State of State o | OLON CIOCAL |
| Density, gm/cc | 1.60 | į – | |
| Charge Wt, Ib | 0.842 | Ì | |
| Total No. of Fragments: | | Method of Loading: | Cast |
| For TNT | 514 | | OEE 0 |
| For Subject HE | 585 | | |
| | *** | Leeding Density: gm/cc | 1.60 |
| Fregment Velocity: ft/sec At 9 ft At 25½ ft | | Storage: | |
| Density, gm/cc | | | |
| | | Method | Dry |
| Blast (Relative to TNT): | | Hazard Class (Quentity-Listance) | Class 9 |
| Air: Peak Pressure | | Compatibility Group | Group I |
| Impulse | | Exudation Exu | des at 65°c |
| Energy | | | |
| Air, Confined: | | | |
| Under Weter: Peak Pressure | | | |
| Impulse | | | |
| Energy | | | |
| Underground: Peak Pressure | | | |
| Impulse | | | |
| Energy | | | |
| | | | |
| | | | |
| | | | |

Tetrytol, 65/35

| Composition: | Molecular Weight: | 264 |
|---|----------------------------------|-------------|
| % Tetryl 65 | Oxygen Belence: | -/ |
| | CO: % CO % | -56 -14 |
| TNT 35 | Density: gm/cc | 1.60 |
| | Melting Point: °C | 68 |
| C/H Ratio | Freezing Point: °C | |
| Impact Sensitivity, 2 Kg Wt: | Boiling Point: °C | |
| Bureau of Mines Apparatus, cm 28 | Refrective Index, no | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. 11 | | |
| Sample Wt, mg 17 | n ₂ | |
| | n ₂₀ | |
| Friction Pendulum Test: | Vecuum Stability Test: | |
| Steel Shoe Cracks | cc/40 Hrs, at | |
| Fiber Shoe Unaffected | • | • 0 |
| Rifle Bullet Impact Test: Trials | 100°C | 2.8 |
| % | 120°C | 11+ |
| Explosions 0 | 135°C | |
| Partials 10 | 150°C | |
| Burned 0 | 200 Grem Bomb Sand Test: | |
| Unaffected 90 | Sand, gm | 52.6 |
| Explosion Temperature: "C | Sensitivity to Initiation: | - |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | |
| | Mercury Fulminate | 0.23* |
| 5 Ignites 325 | Lead Azide | 0.23* |
| 10 | *Alternative initiating charges. | |
| 15 20 | Sellistic Morter, % TNT: | |
| | Trauzi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: Method | - |
| | Condition | |
| 100°C Heat Test: | Confined | |
| % Loss, 1st 48 Hrs | Density, gm/cc | |
| % Loss, 2nd 48 Hrs | Brisance, % TNT | |
| Explosion in 100 Hrs | | |
| Flammability Index: Will not continue to b | urn Confinement | Hone |
| will not continue to b | Condition | Cast |
| Hygrescopicity: % 0.02 | | 1.0 |
| | Density gm/cc | 1.60 |
| | | |

Tetrytol, 65/35

| Fregmentation Test: | | Shaped Charge Effectiveness, TNT = 100 |) : |
|--------------------------------------|-------|--|------------|
| 90 mm HE, M71 Projectile, Let WC-9 | 1: | (d) (e) Glass Cones Steel Co | nes |
| Density, gm/cc | 1.61 | Hole Volume 133 126 | |
| Charge Wt, Ib | 5.010 | Hole Depth 120 119 | |
| Total No. of Fragments: | | Color: | |
| For TNT | 703 | Light yellow t | o buff |
| For Subject HE | 856 | Principal Uses: Bursters, demolitic | |
| 3 inch HE, M42A1 Projectile, Let KC- | 5: | Bursters, demoiling | DIOCER |
| Density, gm/cc | 1.60 | | |
| Charge Wt, Ib | 0.845 | | |
| Total No. of Fragments: | | Method of Loading: | Cp -+: |
| For TNT | 514 | | |
| For Subject HE | 585 | Assilve Design | 1.60 |
| Fregment Velocity: ft/sec | | Leading Density: gm/cc | 1.60 |
| At 9 ft At 251/2 ft | | Storage: | |
| Density, gm/cc | | • | |
| 30.2, 3 , 30 | | Method | Dry |
| Blast (Relative to TNT): | | Hazard Class (Quantity-Distance) | Class 9 |
| Air: | | Compatibility Group | Group I |
| Peak Pressure | | | s at 65°c |
| Impulse | | Exudation Exude | 8 et 65 C |
| Energy | | | |
| Air, Confined: Impulse | | | |
| Under Weter: Peak Pressure | | | |
| Impulse | | | |
| Energy | | | |
| Underground: Peok Pressure | | | |
| Impulse | | | |
| Energy | | | |
| | | 1 | |
| | | | |
| | | | |
| | | | |

Compatibility with Metals:

<u>Dry:</u> Copper, brass, aluminum, magnesium, stainless steel, mild steel mild steel coated with acid proof black paint and mild steel plated with copper, cadmium, zinc or nickel are unaffected. Magnesium-aluminum alloy is slightly affected.

Wet: Stainless steel and mild steel coated with scid-proof black paint are unaffected. Copper, brass, aluminum, magnesium, magnesium-aluminum alloy, mild steel and mild steel plated with cadmium, copper, zinc or nickel are slightly affected.

Preparation:

Tetrytols are manufactured by heating TNT in a melting kettle, equipped with a stirrer, until all the TNT is melted. The necessary amount of tetryl is added and heating and stirring are continued. The temperature is allowed to drop from 100°C until the mixture is of maximum viscosity suitable for pouring. Part of the tetryl dissolves in TNT forming a eutoctic mixture which contains 55 percent tetryl. This mixture freezes at 67.5°C.

Origin:

Tetrytols were developed during World War II. The 70/30 tetryl/TNT castable mixture is the most important in military applications.

References: 74

- (a) L. C. Smith and E. G. Eyster, Physical Testing of Expressives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.
 - (b) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 503, 11 August 1942.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
- (d) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, NDRC Contract W6/2-ORD-5723.
- (e) Eastern Laboratory, du Pont, Investigation of Cavity Effect, Final Report, Eastern Lab, du Pont, 18 September 1943, NDRC Contract W-672-ORD-5,23.
 - (f) Also see the following Picatinny Arsenal Technical Reports on Tetrytol:

| <u>o</u> | <u>1</u> | 2 | <u>3</u> | 2 | <u>6</u> | <u>7</u> | 8 | 2 |
|--------------------------------------|--------------------------------------|------|------------------------------|------------------------------|------------------------------|----------------------|-------------------------------|------|
| 1260 1360 1420 1500 1530 | 1291 1311 1451 1651 1951 | 1372 | 1193 1213 1363 1493 | 1285 1325 1885 2125 | 1376 1436 1466 1506 | 1477 1737 1797 | 1158 1388 18 3 8 | 1379 |

⁷⁴See footnote 1, page 10.

TNT (Trinitrotoluene)

| Composition: | | Molecular Weight: (C | 7 ^H 5 ^N 3 ^O | ₆) | 227 |
|---|--|---|--|----------------|---------------------------|
| С 37.0 | CH ₃ | Oxygen Belence: CO ₂ % CO % | | | -74 -25 |
| N 13.5 | NO ₂ | Density: gm/cc | Crysta | 1 | 1.65 |
| 0 42.3 | | Melting Point: °C | | | 91 |
| C/H Ratio 0.549 | NO ² | Freezing Point: "C | | | |
| Impact Sensitivity, 2 Kg Wt: | | Boiling Point: °C | | | |
| Bureau of Mines Apparatus, cm Sample Wt 20 mg Picatinny Arsenal Apparatus, in. Sample Wt, mg | 95-190+ 14-15 17 | Refrective Index, no | | a B T | 1.5430 1.6742 1.717 |
| Friction Pendulum Test: | | Vocuum Stability Test: | · · · · · · · · · · · · · · · · · · · | | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | | | |
| Fiber Shoe | Unaffected | 90°C | | | 0.10 |
| Rifle Bullet Impact Test: Trials | | - 100°C | | | 0.10 |
| % | | 120°C | | | 0.44 0.23 |
| Explosions 4 | | 150°C | | | 0.65 |
| Partials 0 | | 150 C | | | V. 07 |
| Burned 0 | | 200 Grem Bomb Sand T | est: | | |
| Unaffected 6 | | Sand, gm | | | 48.0 4 |
| Explosion Temperature: °C Seconds, 0.1 (no cap used) 570 | | Sensitivity to Initiation: Minimum Detonating | | , gm | o obx |
| 1 520 5 Decomposes 475 | | Mercury Fulminate | • | | 0.24* 0.27* |
| 10 465 | | Leod Azide | | | 0.21* |
| 15 | | *Alternative initi | uting | charges. | |
| 20 | | Bellistic Morter, % TN | T: | St | d=100 |
| | ······································ | _ Trauzi Test, % TNT: | | St | d=200 |
| 75°C International Heat Test: % Loss in 48 Hrs | 0.04 | Plete Dent Test: Method | A | (a) A | В |
| 100°C Heat Test: | | Condition | Cast | Pi ssed | Cast |
| % Loss, 1st 48 Hrs | 0.2 | Confined | Yes | Yes | No |
| % Loss, 2nd 48 Hrs | 0.2 | Density, gm/cc | 1.61 | 1.50 | 1.61 |
| Explosion in 100 Hrs | None | Brisance, % TNT | 100 | 100 | 100 |
| | | Detonation Rate: | | | |
| Flammability Index: (b) | 100 | Confinement | Un | confined | Unconfin |
| A | | - Condition | Pr | essed | Cast |
| Hygrescepicity: % 30°C, 90% RH | 0.03 | Charge Diameter, in | | | 1.0 |
| Velatility: 30°C | N4.7 | Density, gm/cc | 1. | | 1.56 |
| v oracimy : 30 C | N11 | Rate, nieters/second | 68 | 25 | 66 40 |

TNT (Trinitrotoluene)

| Booster Sensitivity Test: | (c) | | Decomposition Equation: | (h) 10 ^{11.4} | 10 ^{12.2} |
|---|--|--|---|---|--|
| Condition | Pressed | Cast | Oxygen, atoms/sec | 10 | 10,22,2 |
| Tetryl, gm | 100 | 100 | (Z/sec) | 34.4 | 43.4 |
| Wax, in. for 50% Det | onation 1.68 | 0.82 | Heat, kilocalorie/mole (AH, kcal/mol) | 54.4 | 73.4 |
| Wax, gm | | | Temperature Ronge, °C | 275-310 | 23b- 277 |
| Density, gun/cc | 1.55 | 1.60 | Phase | Liquid | Liquid |
| Heat of: | (a) | | _ | | |
| Combustion, cal/gm | • • | 36 20 | Armor Plate Impact Test: | | |
| Explosion, cal/gm | | 1080 | 40 Marka Basicalia | | |
| Gas Voiume, cc/am | 1 | 730 | 60 mm Morter Projectile: 50% Inert, Velocity, ft | /sec | (j) ≯1100 |
| Formation, cal/am | | 78.5 | Aluminum Fineness | , 555 | , |
| _ | | 22.34 | Aldinion inches | | |
| Fusion, col/gm Temperature, OC | | 79 | 500-lb General Purpose Be | ombs: | (3) |
| Specific Heat: cal/gm/*(| c | | Plate Thickness, inches | Trials | % Inert |
| 5 0 | • | 0.309 | risite ittickiness, inches | | W THEI C |
| 20 | | 0.32 8 | 1 . | 0 | |
| 50 80 | | 0.353 | 114 | 0 | |
| 00 | | 0 - 374 | 11,2 | 7 | 100 |
| | | | 134 | 7 | 50 |
| Burning Rote: | | | _ | 7 | ,, |
| cm/sec | | | | | |
| | | | 9 S T | | |
| | | | Bomb Drop Test: | | |
| Thermal Conductivity: | | | - | Piercine Samb | va Concrete: |
| Thermal Conductivity: cal/sec/cm/°C | See next po | age. | Bomb Drop Test: Y7, 2000-lb Semi-Armer-I | Piercing Bomb | vs Concrete: |
| cal/sec/cm/°C | | age. | - | | vs Concrete: 00-6000 |
| cal/sec/cm/°C Coefficient of Expansion: | (b) | | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft | 500 | 00-6000 |
| cal/sec/cm/°C Coefficient of Expansion: Linear, %/°C =40° | (b) | 10 ⁻⁵ (b) | T7, 2000-lb Semi-Armer-I | 500 omb vs Concre | 00-6000 |
| Coefficient of Expension: Linear, %/*C = 40° = 40° | (b) to 60°C 5.4 x to 60°C 6.7 x | 10 ⁻⁵ (b) | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B | 500 omb vs Concre No Seal | 00-6000 Me: Seal |
| Coefficient of Expension: Linear, %/*C = 40° = 40° Volume, %/*C 27° | (b) to 60°C 5.4 x to 60°C 6.7 x | 10 ⁻⁵ (b) | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft | 500 omb vs Concre No Seal 4,000 | 00-6000 He: Seal 4-5,000 |
| Coefficient of Expansion: Linear, %/*C =40° =40° Volume, %/*C 27° 16° | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 1 to 70°C 26.3 | 10 ⁻⁵ (b) 10 ⁻⁵ (b) | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials | 500 omb vs Cencre No Seal 4,000 26 | 00-6000 Me: <u>Seal</u> 4-5,000 20 |
| Coefficient of Expansion: Linear, %/*C =40° =40° Volume, %/*C 27° 16° | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (c) | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected | 500 500 500 500 500 500 500 500 | 00-6000 Ne: Seal 14-5,000 20 |
| Coefficient of Expension: Linear, %/*C = \lambda 0^\text{-100} Volume, %/*C 270\\ 160 Hardness, Mohs' Scale: | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (b) 1.4 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials | 500 500 500 500 500 500 500 500 | 00-6000 Ne: Seal 4-5,000 20 20 0 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -\u00000 -\u00000 Volume, %/°C 27° 16° Herdness, Mohs' Scale: Your-' Medulus: | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (b) 1.4 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected | 500 500 500 500 500 500 500 500 | 00-6000 Ne: Seal 14-5,000 20 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/°C =40° =40° Volume, %/°C 27° 16° Hardness, Mohs' Scale: Your-' Madulus: E', Jynes/cm² | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (c) x 10 ⁻⁵ (c) 1.4 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order | 500 500 500 500 500 500 500 500 | 00-6000 Ne: Seal 4-5,000 20 20 0 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° Volume, %/*C 27° 16° Merdness, Mohs' Scale: Your-' Wedulus: E', uynes/cm² E, lb/inch² | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order | 500 comb vs Cencre No Sea1 4,000 26 24 2 0 | 00-6000 Ne: Seal 4-5,000 20 20 0 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/°C =40° =40° Volume, %/°C 27° 16° Herdness, Mohs' Scale: Your-' Madulus: E', Jynes/cm² | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 10 ⁻⁵ (c) x 10 ⁻⁵ (c) 1.4 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I | 500 comb vs Cencre No Sea1 4,000 26 24 2 0 comb vs Cencre No Sea1 | 00-6000 Ne: Seal 4-5,000 20 20 0 0 0 ste: Seal |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° Volume, %/*C 27° 16° Mardness, Mohs' Scale: Your-' Wedulus: E', uynes/cm² E, lb/inch² Density, gm/cc | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x : to 70°C 26.3 : (e) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) 1.4 (c) 1.4 (c) 1.4 (c) | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I Height, ft | 500 comb vs Cener No Sea1 4,000 26 24 2 0 comb vs Cener No Sea1 5,000 | 00-6000 Ne: Seal 4-5,000 20 20 0 0 ste: Seal 5,000 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/*C = 40° = 10° Volume, %/*C = 27° 16° Merdness, Mohs' Scale: Your-' Vadulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strongth: lb | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I | 500 comb vs Cencre No Sea1 4,000 26 24 2 0 comb vs Cencre No Sea1 | 00-6000 Ne: Seal 4-5,000 20 20 0 0 she: Seal 5,000 26 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° Volume, %/*C 27° 16° Mardness, Mohs' Scale: Your-' Wedulus: E', uynes/cm² E, lb/inch² Density, gm/cc | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) 1.4 (c) 1.4 (c) 1.4 (c) | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I Height, ft | 500 comb vs Cener No Sea1 4,000 26 24 2 0 comb vs Cener No Sea1 5,000 | 00-6000 Ne: Seal 4-5,000 20 20 0 0 ste: Seal 5,000 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -40° -40° Volume, %/°C 27° 16° Herdness, Mohe' Scale: Youn-' Madulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strength: lb Density, gm/cc | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose I Height, ft Trials | 500 comb vs Concre No Sea1 4,000 26 24 2 0 clemb vs Concre No Sea1 5,000 21 | 00-6000 Ne: Seal 4-5,000 20 20 0 0 she: Seal 5,000 26 |
| cal/sec/cm/°C Coefficient of Expession: Linear, %/°C =40° =40° =40° Volume, %/°C 27° 16° Herdness, Mohe' Scale: Your-' Vadulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strongth: lb Density, gm/cc Vaper Pressure: | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e) (b) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 | T7, 2000-lb Semi-Armer-I Max Safe Drop, ft 500-lb General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lb General Purpose B Height, ft Trials Unaffected | 500 somb vs Concre No Seal 4,000 26 24 2 0 0 clomb vs Concre No Seal 5,000 21 18 | 00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -40° -40° -40° Volume, %/°C 27° 16° Mardness, Mohs' Scale: Your-' Vadulus: E', uynes/cm² E, Ib/inch² Density, gm/cc Compressive Strength: Ib Density, gm/cc Vapor Pressure: °C m 80 | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x 3 to 70°C 26.3 3 (e) (b) | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 | Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected | 500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0 | 00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0 |
| col/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° Volume, %/*C =27° 16° Herdness, Mohs' Scale: Your-' Medulus: E', synes/cm² E, lb/inch² Density, gm/cc Compressive Strongth: lb Density, gm/cc Vapor Pressure: | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) /inch² 13800 | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 | Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected | 500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0 | 00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0 |
| Col/sec/cm/°C Coefficient of Expension: Linear, %/*C =40° =40° =40° 10° Volume, %/*C 27° 16° Mardness, Mohe' Scale: Your-' Vadulus: E', uynes/cm² E, lb/inch² Density, gm/cc Compressive Strength: lb Density, gm/cc Vapor Pressure: *C m 80 85 90 | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) /inch² 13800 | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 | Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected | 500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0 | 00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0 |
| cal/sec/cm/°C Coefficient of Expension: Linear, %/°C -40° -40° -40° Volume, %/°C 27° 16° Mardness, Mohs' Scale: Your-' Vadulus: E', uynes/cm² E, Ib/inch² Density, gm/cc Compressive Strongth: Ib Density, gm/cc Vapor Pressure: | (b) to 60°C 5.4 x to 60°C 6.7 x to 80°C 16 x to 70°C 26.3 ; (e) (b) /inch² 13800 | 10 ⁻⁵ (b) 10 ⁻⁵ (b) 20 ⁻⁵ (b) x 10 ⁻⁵ (a) 1.4 5.45 x 10 ¹⁰ 0.79 x 10 ⁶ 161 0-14000 1.62 | Max Safe Drop, ft 500-lib General Purpose B Height, ft Trials Unaffected Low Order High Order 1000-lib General Purpose B Height, ft Trials Unaffected | 500 comb vs Ceneral No Seal 4,000 26 24 2 0 comb vs Ceneral No Seal 5,000 21 18 0 | 00-6000 Ne: Seal 4-5,000 20 0 0 0 ste: Seal 5,000 26 22 0 |

INT (Trinitrotoluene)

| Fregmentation Yest: | | Shaped Charge Effectiveness, TNT = 100: | |
|--|---|---|-----|
| 90 xam HE, M71 Projectile, Let WC-91 | e (1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1 | Gécus Cones Steel Cones | |
| Density, gm/cc | 1.60 | Hice Volume 100 100 | |
| Charge Wt, Ib | 2.104 | Hole Depth 100 100 | |
| Total No. of Fragments: | | Color: Light yellow | _ |
| For TNT | 703 | | |
| For Subject HE | 703 | Principal Uses: GP bombs, PE projectiles, | _ |
| 3 inch HE, M42A1 Projectile, Let KC-5 | | demolition charges, depth charges, | |
| | 1.60 | grenades, propellant compositions | |
| Density, gm/cc | 0.848 | | |
| Charga Wt, Ib | U+040 | | |
| Total No. of Fragments: | | Author of Lording: 1. Cast | |
| For TNT | 514 | Atothod of Leading: 1. Cast 2. Pressed | |
| For Subject HE | 314 | | |
| e e | | Leading Density: gm/cc See below | |
| Fragment Velocity: ft/sec | (k) | | |
| At 9 ft At 251/4 ft | 8500 8500 | Storage: | _ |
| Pensity, gm/cc | 1.58 | | |
| | | Method Dry | |
| Stast (Kelative to TNT): | ······ | Hazard Class \(\triangle\tau\) uontity-Distance) Class 9 | |
| Aia | | Compatibility Group Group I | |
| Peak Pressure | 100 | | |
| Impulse | 100 | Exudotion None at 65°C | |
| Energy | 100 | | |
| Air, Confine. | | Loading Density: gm/cc | |
| Impulse | 100 | 1. Cast 1.58-1.59 2. Pressed psi x 103 | |
| Under Water: | | 3 5 10 15 20 30 5 | 0 |
| Peak Pressure | 100 | 1.35 1.40 1.45 1.52 1.55 1.59 1 | . (|
| Impuise | 100 | Thermal Conductivity: | |
| Energy | 100 | cal/sec/cm/OC | |
| Underground: | | Density 1.19 gm/cc (g) 5.28 x 10 4 | |
| Peak Pressure | 100 | 1.51 gm/cc (g) 7.12 x 10 ⁻¹ 1.54 gm/cc (t) 5.6 x 10 ⁻¹ | |
| Impulse | 100 | 1.67 gm/cc (g) 12.21 x 10 ⁻⁴ | |
| Energy | 100 | Viscosity, poises: | |
| | | Tem, 85°C 0.139 | |
| e de la companya de | | Bulk Mcd. J. s at Room | |
| | | Temperature (25°-30°C): (m) | |
| | | Dynes/cm x 10 10 2.92 Density, gm/cc 1.56 | |

TWT (Trinitrotoluene)

| Effect of Temperature on Rate of | of Detons | tion: (1 |) | |
|----------------------------------|-----------|----------|------|------|
| Temperature of Charge, OC | -54 | 21 | ۵ | 60 |
| Sours at Temperature | 16 | 16 | 24 | 72 |
| Density, gm/cc | 1.63 | 1.62 | 1.64 | 1.64 |
| Pate, maters/second | 6700 | 6820 | 6770 | 6510 |
| | | | | |

Sensitivity to Electrostatic Discharge, Joules; Through 100 Mesh:

Unconfined 0.36 Confined 4.4

Impact Sensitivit, versus Temp rature:

Picatincy Arsensi Apparatos, 2 mg wt, inches:

| <u> </u> | , | | inches | | |
|----------|------|-----|--------|-----------|--------|
| -40 | | 4 4 | 17 | + 2 | |
| Room | | | 14 | | • |
| 80 | | | 7 | | |
| . 90 | | • | 3 , : | | |
| 105-110 | | | 2 (5 e | explin 20 | trials |

Demact Sensitivity versus Loading Mathod, Large Espect Apparatus, Inches:

Pressed at 1.60 gm/ce 70 Cast at 50 gm/cr 26

Rifle Fallet Dynes Sensivity versus Tempareture, Confinement:

| Standard Iron Bomb: | Room Tempera tur | <u> </u> | 105° | to 110°C |
|--|---------------------|----------|------|----------|
| No Air Space Trials Explosions | 10 1 very low ox | der | 4. | 10 7 |
| Air Space Trials Explosions | 10 | | ¥. | 10 0 |
| Tin or Cardboard Bombs: | | | £., | |
| With or Without Air Space Trials Logions | 10 | | \$1 | 10 0 |

int (Trinitrotolusse)

Prologion Temperature versus TET Initie Temperature:

| THT Temperature, Initial | Explosion Pemperature, OC |
|--|--------------------------------------|
| Room 105°-100°C | 470 (Decomposes) 480 (Decomposes) |
| plosion Emperature versus Confinement, | , °C: |

Unconfined Sealed in glass capillary

Viscosity at 80.5°C:

Viscosity, X, cp log X = 0.046 S + 1.26 S = \$ solid in slurry Particle size effect, small

Density, gw/ce:

| <u>°c</u> | State | gra/cc |
|----------------|----------|--------|
| 27 to 70 80 | Flaked | 1.65 |
| 8o 💥 | Flaked | 1.64 |
| 82 | Liquid | 1.48 |
| `. <u>.</u> 87 | Taking a | 1.48 |
| .95 | Liquid | 1.47 |

Solubility of Ter, gra/100 gra (\$), in: (f)

| <u>ila</u> | <u>ter</u> | Ace | tone | <u> 2</u> | enzene | To | luene |
|---------------------|--------------------------------------|---------------------|-------------------------|----------------------|---------------------------------|----------------------|---------------------------------|
| <u>့ ဗ</u> င | _ 1 | <u>°c</u> . | £ | °C | £ | OC : | |
| 0 20 40 60 | 0.0100 0.0130 0.0285 0.0675 | 0 20 40 60 | 57 109 226 600 | 90 40 60 80 | 13 67 180 478 >2000 | 90 90 80 90 | 28 55 130 367 71700 |
| Č | arbon | | | | | The in | hī owo- |

| | Carbon chloride | <u>Rti</u> | ber | Chlore | oform | Trichlo ethyle |
|----------------|------------------------|------------|--------------|---------------|---------------|-------------------|
| <u>°c</u> | £ | °c | 2 | °c | <u> </u> | 0,, |
| 0 | 0.20 0.35 1.75 | 0 20 | 1.73 3.29 | 0 20 40 | 6 19 66 | 25 55 |
| 60 70 75 | 6.90 17-34 24.35 | | | 60 | 302 | |

TMT (Trinitrotoluene)

| Pyr | dine | Methyl | acetate | | vlene loride | | boxy- acetate |
|----------------|-------------------|----------------|------------------|----------------|------------------|----------------|------------------|
| o _C | 5 | <u>°c</u> | ž | <u>°c</u> | \$ | <u>°∟</u> | |
| 20 40 ú0 | 140 250 640 | 20 40 50 | 73 135 260 | 20 40 60 | 34 123 460 | 20 40 50 | 29.5 49 96 |
| 70 | 1050 | • | | | | _ | |

| | chloro- | . At | niline | | bol | Ethe | anol |
|----------------|-----------------|----------------------------|--------------------------------|----------------|----------------------|---------------------------|-----------------------------------|
| <u>ိင</u> | ź | °c | ž | °c | £ | <u>်</u> င | 2 |
| 20 40 50 | 18 50 100 | 10 30 50 70 80 | 6.1 11.5 29 74 130 | 20 40 50 | 0.76 1.96 2.95 | o 20 40 60 70 | 0.62 1.25 2.85 8.4 15 |

| Isobutyl | alcohol | Carbon d | isulfide | Chloro | benzene |
|-----------|---------|-----------|----------|------------|----------------|
| <u>°c</u> | £ | <u>°с</u> | . 2 | <u>°c</u> | ž |
| 0 | 0.20 | 0 | 0.14 | 20 | 5 5 |
| 20 | 0.61 | 20 | 0.44 | 3 € | 51 |
| 40 | 1.41 | 40 | 1.4 | 40 | 79 |
| 50 | 2.35 | | | 50 | 116 |

Preparation.

(AC 7258, 7259, 7260 - Mitration Kinetics) (Chemistry of Powder and Explosives, Davis)

In older processes trinitrotoluene (TMT) was slowly and laboriously nitrated in three stages using successively stronger acids. Today, however, a single stage nitration is possible, in a short time (less than one hour) producing TMT at a cost of a little less than 66/lo. In England, a two stage continuous process was developed during World War II; in the first counter current stage, to me was nitrated to the mono stage mononitrotoluene (MMT); in the second stage, also count current, MMB was nitrated to TMT.

TNT (Trinitrotoluene)

It was the British work, on the kinetics of nitration of toluene to TNT, that first pointed out the basic importance to nitration processes of the nitroxyl ion (NO_2^+) , on the one hand, and the role of the bisulfate ion (RSO_4^+) and unionized sulfuric acid on the other. These concepts were successful in explaining the maximum in nitration rate occurring at a sulfuric acid content of 92%. This work, for instance, leads to the following equation for the rate of formation of TNT from DNT:

$$\frac{q \left(LML\right)}{q \left(LML\right)} = K \left(H0^{5+}\right) \left[K, \left(H20^{\beta}-\right) + K, \left(H^{5}20^{\beta}\right)\right] \left(LML\right)$$

Inree Stage Process: Toluene (100 gm) is nitrated to the mono derivative by slowly adding a mixture of 294 gm sulfuric acid (sp gr 1.84) and 147 gm nitric acid (sp gr 1.42) to it at 30°-40°C, with good agitation. Acid addition requires 1-1.5 hour, and stirring at 30°-40°C is continued 30 minutes longer. The mixture is cooled and the lower layer of spent acid drawn off.

Half the crude mono is dissolved in 109 gm sulfuric acid (sp gr 1.84) with cooling, the solution heated to 50°C and a mixture of 54.5 gm nitric acid (sp gr 1.50) and 54.5 gm sulfuric acid (sp gr 1.84) added, under agitation, at such a rate that the temperature is maintained between 90° and 100°C. Acid addition requires 1 hour, and stirring at 90°-100°C is continued 2 more hours.

While the dinitration mixture is still at 90°C, 145 gm fuming sulfuric acid (cleum containing 15% free SO₃) is added slowly. A mixed acid of 92.5 gm each nitric acid (sp gr 1.50) and 15% cleum is slivly added, under good agitation at 100°-11 'over 1½-2 hours. The mixture is stirred at 100°-115°C for 2 more hours, cooled, filtered, and the TMT cake broken up and washed with water. The TMT is washed 3-4 times with hot water (85°-95°C) with good agitation. The project can be purified either by recrystallization from alcohol or by washing it with 5 times its weight of 5% sodium bisulfite solution at 90°C for ½ hour with vigorous stirring, washing with hot water until the washings are colorless, and cooling slowly with stirring to granulate the product.

Origin:

TWT was first prepared in 1863 by Wilbrand (Ann 128, 178), later by feilstein and Kuhlberg (Ber 3, 202 (1870) and also Tiemann (Ber 3, 217 (1870), each using different methods of starting materials. It was nearly 30 years later when Hausermann undertook its manufacture on an industrial scale (Z angew Chem, 1891, p. 508; J Chem Ind., 1891, p. 1028). After 1901 TWT began to be used extensively as a military explosive and Germany became the first nation to adopt it as a standard shell filler (1902-1904). During World War I all the major powers of the world were using TWT, with the quantity used limited only by the available supply of toluene. Prior to World War II the development of synthesic toluene from petroleum made available in the United States, an almost unlimited supply of this raw material. Because of the general suitability of TWT for melt-loading and its extensive use in binary and ternary explosive mixtures, TWT is considered the most important military explosive known today.

Destruction by Chemical Decomposition:

THT is decomposed by adding it slowly, while stirring, to 30 times its weight of a solution prepared by dissolving 1 part of sodium sulfide (Ma_2S-9H_2O) is 6 parts of water.

References:75

(a) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.

⁷⁵See footnote 1, page 10.

TWT (Trinitrotoluene)

- (b) Philip C. Keenan and Dorothy Pipes, Table of Military High Explosives, Second Rovision, MAYORD Report Mo. 87-46, 26 July 1946.
- (c) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, HOL Nemo 10,303, 15 June 1949.
- (d) L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Parformance Tests, OSED Report No. 5746, 27 December 1945.
 - (e) Report AC-2587.
 - (f) International Critical Tables and various other sources in the open literature.
- (g) E. Hutchinson, The Thermal Sensitiveness of Explosives. The Thermal Conductivity of Explosive Materials, AC-2501, First Report, August 1942.
 - (h) A. J. B. Robertson, Trans Parad Society, 44: 977 (1948).
- (i) M. A. Cook and M. T. Abegg, "Isothermal Decomposition of Explosives," University of Utah, Ind Eng Chem (June 1956), pp. 1090-1095.
- (j) Committée of Div 2 and 8, NDRC, Report on NET and Tritonal, OSRD No. 5406, 31 July 1945.
- (k) R. W. Drake, Fragment Velocity and Panel Penetration of Several Explosives in Simulated Shells, OSRD Report No. 5622, 2 January 1946.
- (1) W. J. McGarry and T. W. Stevens, Detonation Rates of the More Important Military Explosives at Several Different Temperatures, PATR Ro. 2353, November 1956.
- (m) W. S. Cramer, "wilk Compressibility Data on Several High Emplosives, NAVORD Report No. 4380, 15 September 1956.
 - (n) Kentrov, Journal of Chemical Industry (Russia) 6, 1929, pp. 1686-1688.
 - (o) Also see the following Picatinny Argenal Technical Reports on TRT:

| 0 0 | 1 | 2 | 3 | 4 | 2 | <u>6</u> | 1 | <u>8</u> | 2 |
|------------|------|--------------|------|------|------|------------|------|----------|------|
| 10 | 291 | 132 | 43 | 364 | 65 | 86 | 47 | 118 | : 99 |
| 30 240 | 551 | 582 | 83 | 694 | 195 | 266 | 87 | 283 | 249 |
| 240 | 731 | 782 | 133 | 874 | 125 | 556 | 507 | 638 | 269 |
| 350 | 861 | 892 | 273 | 904 | 555 | 556 666 | 527 | 738 | 319 |
| 630 | 891 | 972 | 513 | 1094 | 695 | 956 986 | 597 | 768 | 389 |
| 760 | 901 | 1072 | 643 | 1104 | 735 | 986 | 707 | 838 | 499 |
| 810 | 971 | 1182 | 673 | 1124 | 805 | 1046 | 807 | 1388 | 709 |
| 1120 | 1041 | 1192 | 743 | 1224 | 975 | 1146 | 817 | 1098 | 739 |
| 1140 | 1121 | 1272 | 853 | 1284 | 1145 | 1276 | 537 | 1128 | 779 |
| 1170 | 1311 | 1292 1342 | 863 | 1294 | 1155 | 1376 | 1107 | 1148 | 799 |
| 1260 | 1391 | 1342 | 1063 | 1304 | 1225 | 1446 | 1147 | 1158 | 889 |
| 1270 | 1431 | 1352 | 1123 | 1314 | 1285 | 1466 | 1217 | 1188 | 929 |
| 1360 | 1451 | 1372 | 1133 | 1344 | 1305 | 1476 | 1247 | 1198 | 939 |
| 1460 | 1491 | 1402 | 1193 | 1414 | 1315 | 1556 | 1307 | 1228 | 1099 |
| 1460 | 1651 | 1452 | 1243 | 1444 | 1395 | 1636 | 1417 | 1258 | 1109 |
| 1500 | 1821 | 1472 | 1,23 | 1454 | 1425 | 1756 | 1427 | 1308 | 1129 |

AMCP 706-177 TMT (Trinitrotoluere) <u>6</u> 1435 1445 1495 1515 1535 1565 1665 1665 1865 1715 1885 2125 2175 <u>e</u> <u>4</u> I 1562 1582 1712 1862 2216 1540 1550 1730 2010 2100 2160 1493 1553 1633 1693 1823 2063 2163 1544 1564 1604 1674 1754 1924 2064 1457 1497 1537 1547 1557 1577 1577 1677 1737 1797 1827 1847 2007 2147 2167 1336 1368 1418 1426 1576 1618 1688 1726 1826 1838 2008 2136 2168 1179 1259 1289 1369 1379 1419 1429 1469 1529 1629 1749 1749 1809 1819 1819 1949 2159 2179

Torpex

| Composition: | | Molecular Weight: | 97 |
|--|------|-------------------------------|---------------------|
| RDX | 42 | Oxygen Belence: | |
| TKT | 40 | CO: % | -55 - 2 6 |
| Aluminum | 18 | Density: gm/cc Cast | 1.76-1.81 |
| | | Mailing Point: *C | |
| C/H Ratio | | Freezing Point: "C | |
| Impact Sonshivity, 2 Kg Wt: | | Beiling Point: *C | |
| Bureou of Mines Apparatus, cm Sample Wt 20 mg | 42 | Befreethe Index - D | |
| Picatinny Arsenal Apparatus, in. | 9 | Refrective Index, no | |
| Sample Wt, mg | 15 | n _m | |
| | | r. | |
| Friction Pondulum Test: | | Vesuum Stability Test: | |
| Steel Shoe | | cc/40 Hrs, at | |
| Fiber Shoe | | 90.C | |
| Diffe Bullet Impact Tests Tests | | 100.C | |
| Rifie Bullet Impact Test: Trials | | 120°C | 1.0 |
| % Explosions 20 | | 135°C | |
| Partials 80 | 4. | 150°C | |
| | | | |
| | | 200 Grem Bomb Sond Yest: | |
| Unaffected 0 | | Sand, gm | 59.5 |
| Explains Temperature: °C | | Sessitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | | Minimum Detonating Charge, gm | |
| 5 Decorposes 260 | | Mercury Fulminate | 0.18 |
| 5 Decomposes 260 | | Leod Azide | |
| 10 | | Tetry, | |
| 15 | | Bellistic Morter, % TNT: (a) | |
| 20 | | | 138 |
| 75°C International Heat Test: | | Trouzi Test, % TNT: (b) | 164 |
| % Loss in 48 Hrs | | Plate Dent Test: (c) Method | В |
| 100°C Heet Test: | | Condition | Cast |
| % Loss. 1st 48 Hrs | 0.00 | Confined | No |
| % Loss, 2nd 48 Hrs | | Density, gm/cc | 1.83 |
| Explosion in 100 Hrs | 0.10 | Brisance, % TNT | 120 |
| Expresion in 100 rits | None | | |
| Flommobility Index: | 196 | Confinement | None |
| | | Condition | Cast |
| Hygrescepicity: % 30°C, 90% RH | 0.00 | Charge Diameter, in. | 1.0 |
| | | Density, gm/cc | |
| Velatility: | | | 1.81 |
| | | Rate, meter://second | 7495 |

| Gos Volume, cc/gm Formation, cal/gm Fusion, cal/gm Specific Meet: cal/gm/°C At -5°C Density, gm/cc At 15°C Density, gm/cc At 15°C Bearing Rete: cm/sec Thermed Conductivity: cal/sec/cm/°C Density, gm/cc Volume, %/°C Mardian: Meins Scale: Young's Modulus: E', dynes/cm ³ Density, gm/cc Density, gm/cc Density, gm/cc 18 Sol inert, Velocity, ft/sec Aluminum Fineness Sol inert, Velocity, ft/sec Aluminum Fineness Sol inert, Velocity, ft/sec Aluminum Fineness Sol inert, Velocity, ft/sec Aluminum Fineness 10 Plate Thickness, inches 11/4 11/4 11/4 11/4 11/4 11/4 11/4 11 | Booster Sensitivity Test: Condition | (c) Pressed | Casc | Decemposition Equation: Oxygen, atoms/sec | |
|--|--|--|---------------------|---|----------------|
| Wex, gm 2 0 Density, gm/cc 1.64. 1.81 Heat of: Combustion, col/gm 1800 Gos Volume, cc/gm Formation, col/gm Euplosion, col/gm Fusion, usion Fusion Fusion, col/gm Fusion | Tetryl, gm | 10 | 5 | | |
| Wax, gm | Wax, in. for 50% Detant | stion | | | |
| Density, gm/cc 1.64 1.81 Phase | Wax, gm | 2 | 0 | | |
| Combustion, col/gm 1800 Gas Volume, cc/gm Formation, col/gm Fusion, col/gm Fusion, col/gm Specific Neet: col/gm/*C (b) At -5°C 0.22 Density, gm/ce 1.82 At 15°C 0.24 Barning Rate: cm/sec Thermal Conductivity: col/sec/cm/*C 9.7 x 10 ⁻¹⁶ Density, gm/ce 1.82 Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C -73 to 75°C 4.7 x 10 ⁻⁶ E, ib/inch* 1.38 x 10 ⁶ Density, gm/cc 1.77 Compressive Strength: Ib/inch* (b) 2100-2300 Density, gm/cc Vaper Pressure: Aluminum Fineness 508 Inert, Velocity, ff/sec 18 68 mm Merier Projectile: 50% Inert, Velocity, ff/sec 18 60 mm Merter Projection: 50% Inert, Velocity, ff/sec 18 50% Inert, Velocity, ff/se | Density, gm/cc | 1.64 | 1.81 | 1 | |
| Explosion, col/gm Gas Volume, cc/gm Formation, col/gm Fusion, Fusion, col/gm Fusion Fusio | | (a) | | A man Minte I man Man I | |
| Gos Volume, cc/gm Formaticn, cal/gm Fusion, cal/gm Specific Meet: cal/gm/°C At -5°C Density, gm/cc At 15°C Density, gm/cc At 15°C Thermal Conductivity: cal/sec/cm/°C Density, gm/cc Linear, %/°C -73 to 75°C h.7 x 10 ⁻⁵ (b) Volume, %/°C Wolume, %/°C Fighred Medulus: E, lb/inch² Density, gm/cc Density, gm/cc Thermal Conductivity: cal/sec/cm/°C Density Medulus: E, lb/inch² Density, gm/cc Linear, %/°C Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order Height, ft Triols Unaffected Low Order | Combustion, cal/gm | | 3740 | Armor Fiera Impact 1001: | |
| Gos Volume, cc/gm Formation, cal/gm Specific Heat: cal/gm/*C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24 Burning Rate: cm/sec Thermal Conductivity: (b) cal/sec/cm/*C 9.7 x 10 ⁻¹⁴ Density, gm/cc 1.82 Coefficient of Expansing: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Height, ft Trials Unaffected Low Order Height, gm/cc Unaffected Low Order Height, gm/cc Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order | Explosion, col/gm | | 1800 | 60 mm Morter Projection | (•) |
| Fusion, ca:/gm Specific Meet: cal/gm/*C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24 Surning Rate: cm/sec Semb Drep Test: Thermal Conductivity: cal/sec/cm/*C 9.7 x 10°-14 Density, gm/cc 1.82 Coefficient of Expansing: Linear, %/*C -73 to 75°C 1.7 x 10°-5 (b) Volume, %/*C Volume, %/*C Volume, %/*C Young's Medulus: E', dynes/cm ³ 9.53 x 106 E, lb/inch ³ 1.38 x 106 Density, gm/cc 1.77 Compressive Strength: lh/inch ⁴ (b) 2100-2300 Density, gm/cc 1.77 Value Fressure: Semb Drep Test: T7, 2000-15 Semi-Armor-Piercing Bernb vs Concrete: Height, ft Trials Unaffected Low Order Height, ft Trials Unaffected Low Order | Gas Volume, cc/gm | | | | 185 |
| Specific Most: cal/gm/*C (b) At -5°C 0.22 Density, gm/cc 1.82 At 15°C 0.24 Burning Rate: cm/sec Samb Brep Test: Thermal Conductivity: (b) cal/sec/cm/*C 9.7 x 10 ⁻¹⁴ Density, gm/cc 1.82 Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Wang's Medulus: (b) E', dynes/cm² 9.53 x 10 ⁶ E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2102-2300 Density, gm/cc Vaper Pressure: Sob th General Purpose Bombs: Plate Thickness, inches 1 1/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 11/4 11/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/4 13/2 13/4 13/4 13/2 13/4 13/4 13/4 13/2 13/4 13/4 13/4 13/2 13/4 13/4 13/4 13/4 13/4 13/4 13/4 13/4 | Formation, cal/gm | | | Aluminum Fineness | • |
| Specific Meet: cal/gm/*C (b) At -5°C 0.22 Plate Thickness, inches Density, gm/cc 1.82 1 At 15°C 0.24 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1½ 1 | Fusion, ca!/gm | | | 1 | |
| At -5°C 0.22 Plate Thickness, inches Density, gm/cc 1.82 1 1 1 1 1 1 1 1 1 | Sandin Mark and an 195 | /s\ | | 500-lb Ganaral Puryase Bombs: | • |
| Surning Rate: Confident of Expansion: | | (0) | 0.22 | Plate Thickness, inches | |
| Burning Rate: cm/sec Thermal Conductivity: (b) | Density, gm/cc | | 1.82 | 1 | |
| Surning Rate: cm/sec | (A 3 E O G | | o ob | 11/4 | |
| Burning Rate: cm/sec Thermal Conductivity: col/sec/cm/*C Density, gm/cc Coefficient of Expension: Linear, %/*C = 73 to 75°C ¼.7 x 10 ⁻⁵ (b) Volume, %/*C Height, ft Triols Unaffected Low Order i-ligh Order E, dynes/cm² 9.53 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2109-2300 Density, gm/cc Vapor Pressure: Valume Samb Drop Test: T7, 2000-lb Semi-Armer-Plercing Berab vs Cand Amax Safe Drop, ft 500-lb General Purpose Bemb vs Concrete: Height, ft Triols 1.38 x 10 1000-lb General Purpose Bemb vs Concrete: Height, ft Triols Unoffected Low Order | At 1) C | | 0.24 | · · · | |
| Berning Rate: cm/sec Thermal Conductivity: cal/sec/cm/*C 9.7 x 10 ⁻¹⁴ Density, gm/ce 1.82 Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Height, ft Trials Unaffected Low Order i-ligh Order F, dynes/cm² 9.53 x 10 ⁶ E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Samb Drop Test: T7, 2000-ib Semi-Armor-Plorcing Bernb vs Concrete: Height, ft Trials Unaffected Low Order i-ligh Order 1000-ib Genural Purpose Bamb vs Concrete: Height, ft Trials Unaffected Low Order Unaffected Low Order | | | | ·- | |
| Thermal Conductivity: (b) cal/sec/em/*C Density, gm/cc Coefficient of Expension: Linear, %/*C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/*C Young's Medulus: (b) E', dynes/cm² 9.53 x 10 ⁶ E, lb/inch² 1.38 x 10 Density, gm/cc Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc Vapor Pressure: T7, 2000-ib Semi-Armor-Plorsing Bornb vs Const Max Safe Drop, ft S00-ib Gensrel Purpose Bomb vs Constructe: Height, ft Trials Unaffected Low Order i-ligh Order Height, ft Trials Unaffected Low Order Trials Unaffected Low Order | | | | • | |
| Coefficient of Expension: Linear, %/°C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/°C Young's Medulus: E', dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc Vapor Pressure: T7, 2000-lb Semi-Armer-Ploreing Bornb vs Concrete: Max Safe Drop, ft S00-lb General Purpose Bomb vs Concrete: Height, ft Triois Low Order i-ligh Order 1.000-lb Genural Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order Trials Unoffected Low Order | | | | Somb Drop Test: | |
| Coefficient of Expension: Linear, %/°C -73 to 75°C 4.7 x 10 ⁻⁵ (b) Volume, %/°C Height, ft Trials Unaffected Low Order F, dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc Tous Generate: Max Safe Drop, ft S00-th Generat Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order Fligh Order 1.77 Height, ft Trials Unoffected Low Order Fligh Order 1.77 Unoffected Unoffected Low Order Low Order Low Order | cal/sec/cm/°C | (b) 9 | | T7, 2000-15 Semi-Armor-Plotting Born | b vs Concrita: |
| Volume, %/°C Height, ft Triois Unaffected Low Order High Order I 38 x 10 Density, gm/cc Veper Pressure: Height, ft Triois Unaffected Low Order High Order 1.38 x 10 1.000-th Genural Purpose Bamb vs Concrete: Unoffected Low Order Height, ft Trials Unoffected Low Order Low Order Unoffected Low Order | | | | Max Safe Drop, ft | |
| Young's Medius: (b) E', dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Preight, Trials Unaffected Low Order iligh Order 1000-th Genural Purpose Bamb vs Concrete: Height, ft Trials Unaffected Low Order | Linear, %/°C -73 to | 75°C 4.7 x 10 | o ⁻⁵ (b) | 500-7b General Purpose Bemb vs Con- | crefe; |
| Young's Medicia: E', dynes/cm² 9.53 x 10 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc 1.77 Unaffected Low Order High Order 1.000-lb Genural Purpose Bomb vs Concrete: Height, ft Trials Unaffected Low Order | Volume, %/°C | | | Height, ft | |
| Voung's Mediulus: E', dynes/cm² 9.53 x 106 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Unaffected Low Order High Order 1.000-th Genural Purpose Bamb vs Concrete: Unaffected Low Order | | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | | Trials | |
| Young's Modulus: (b) E', dynes/cm² 9.53 x 106 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lb/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Low Order High Order 1.000-lb Genural Purpose Bamb vs Concrete: Unoffected Low Order | Mardia Maine Scole: | | | Unaffected | |
| E', dynes/cm² 9.53 x 106 E, lb/inch² 1.38 x 10 Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: (b) iligh Order 1000-th Genural Purpose Bomb vs Concrete: Height, ft Trials Unoffected Low Order | | | | Low Order | |
| E, lb/inch² Density, gm/cc 1.38 x 10 1.000-lb Genural Purpose Bomb vs Concrete: Height, ft Trials Unoffected Low Order | • | (b) | 10 | 1 | |
| Density, gm/cc 1.77 Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Height, ft Trials Unoffected Low Order | • • | 9.53 | x 10_6 | 1.1. | |
| Density, gm/cc 1.77 Height, ft Compressive Strength: lh/inch² (b) 2100-2300 Density, gm/cc 1.77 Height, ft Trials Unoffected Low Order | | - | | 1000-lb General Purpose Bomb vs Con- | crate; |
| Compressive Strength: It/inch² (b) 2100-2300 Density, gm/cc 1.77 Vapor Pressure: Trials Unoffected Low Order | Density, gm/cc | ; | L.77 | | |
| Density, gm/cc 1.77 Unoffected Vapor Pressure: Low Order | Compressive Strengths It /inc | hi (b) 2100 | 0-2300 | 1 | |
| Vapor Pressure: Low Order | | | | 1 | |
| | | | 11 | 1 | |
| mm Mercury High Order | | | | | • |
| | TC mm A | Aercury | | High Order | |
| | | | | | |
| l l | | | | | |
| | | | | | |

| Fregmentation Test: | | Sheped Charge Effectiveness, TNT = 1 50/36.5/13. | 00: 5 |
|----------------------------------|-----------------------|---|-----------------|
| 90 mm HE, M71 Projectile, Let W | C-01: | Glass Cones Sterl (| |
| Density, grn/cc | 1.75 | Hole Volume 150 14 | 5 |
| Charge Wt, Ib | 2.316 | Hole Depth 127 13 | 1 |
| Total No. of Fragments: | | Color: | Gray |
| For TNT | 703 | • | Olay |
| For Subject HE | 891 | Principal Uses: Depth charges, be | omba |
| 3 lack HE, M42A1 Projectile, Let | KC-5: | pepul unitable, t | |
| Density, gm/cc | 1.79 | | |
| Charge Wt, Ib | 0.940 | | |
| Total No. of Fragments: | | Method of Leading: | Cast |
| For TNT | 514 | | |
| For Subject HE | 647 | Leading Density: gm/cc | 1.76-1.81 |
| Fregment Velocity: ft/sec | | Lessing Genny: gm/cc | 1110-1101 |
| Át 9 ft | 2960 28 0 0 | | |
| At 251/4 ft | | Storage: | |
| Density, gm/cc | | Method | Dry |
| Black (Relative to TNT): | (e) | h'nzard (Joss (Quantity-Distance) | Class 9 |
| Ain | | Compatibility Group | Group I |
| Peak Pressure | 122 | i | |
| Impulse | 125 | \"xudation | |
| Energy | 146 | | |
| Air, Confined: | 116 | Effect of Temperature on Impert Sensitivity: | |
| • | | Tem. PA Inpact Test | |
| Under Weter: | 226 | 2 Kg Wt, inches | |
| Peak Pressure | 116 | 25 15 | |
| Impulse | 127 | i 32 7 | |
| Energy | 153 | 104 | |
| Underground: Peak Pressure | | Viscosity, poises: | |
| Impulse | | Т ещ р, 83 ⁰ С | 4.5 |
| Energy | | 95°C | 2.3 |
| | | | |
| | | | |
| | | 1 | |
| | | | |

Preparation:

Torpex is manufactured by heating TNT to approximately 100°C in a steam-jacketed kettle equipped with a stirrer. Water wet RDK is added slowly to the molten TNT, while mixing and heating, until all the water is evaporated. Aluminum is added and the mixture is stirred until uniform. The mixture is cooled, with continued attring, until it is suitable for pouring. Torpex can also be made by adding the calculated amount of TNT to Composition B to maintain the desired proportion of RDK/TNT, heating and stirring, and adding 18 percent of aluminum to complete the mixture.

Origin:

Turpex, a castable high explosive, was developed in England during World War II for use as a filler in warheads, mines and depth bombs. Several variations in the composition of torpex have been evaluated but the following are those used in survice munitions:

| | Torpex 2 unwared | Torpex 2 waxed | Trans. 3 |
|---|---------------------|-----------------------------|------------------------------------|
| | (a) | (b) | (c) |
| RIX, \$ THT, \$ Aluminum, \$ Wax. \$ Calcium chloride, \$ | 42 40 18 | 41.6 39.7 18.0 0.7 | 41.4 39.5 17.9 0.7 0.5 |

- (a) Made from Composition B-2 or 60/40 Cycletol.
- (b) Made by the addition of aluminum to Composition B.
- (c) Made by the addition of calcium chloride to Torpex 2.

Wax has the undesirable effect of (1) tending to congulate the aluminum, thus giving a less homogeneous and more viscous product, (2) lowering the density of the cast explosive from 1.72-1.75 to 1.56-1.70 for waxed torper, and (3) lowering the compressive strength from 3700 psi to 1970 psi for waxed torper. However, wax is used in service torpex for reasons of safety, since there is evidence that its presence lowers the sensitivity of the explosive to impact as measured by laboratory drop tests and bullet sensitivity tests of small charges (Bureau of Ord Res Memo Rpt No. 24, January 1945).

References: 76

- (a) Committee of Div 2 and 8, NDRC, Report on HBX and Tritonal, OSRD No. 5406, 31 July 1945.
- (b) Philip C. Keenan and Dorothy C. Pipes, Table of Military High Explosives, Second Revision, HAVORD Report No. 87-46, 26 July 1946.
 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- L. C. Smith and E. H. Eyster, Physical Testing of Explosives, Part III, Miscellaneous Sensitivity Tests, Performance Tests, OSRD Report No. 5746, 27 December 1945.

⁷⁶See footnote 1, page 10.

Torpe:

- (d) G. H. Messerly, The Exte of Detonation of Various Explosive Compounds, OSRD Report No. 1219, 22 February 1943.
- M. D. Hurwitz, The Rate of Detonation of Various Compounds and Mixtures, OSRD Report No. 5611, 15 January 1946.
- (e) 1. Tomlinson, Jr., Blast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1980.
- (f) Eastern Laboratory du Pont, Investigation of Cavity Effect, Sec III, Variation of Cavity Effect with Explosive Composition, MIRC Contract W672-0RD-5723.
 - (6) Also see the following Picatinny Arsenal Technical Reports on Torpex:

8 <u>6</u> 1 <u>o</u> <u>1</u> 2 ٤ 2 1585 1635 1885 2355 18**38** 1651 1796 1797 1530 1292 2353



1,3,5-Triamino-2,4,6-Trinitrobenzene (TATMB)

| Composition: | | Melecular Weight: (C6E6N606) | 258 |
|--|---------------------------------|--|-----------------|
| с 27.9 н 2.3 о ₂ м — | NH ₂ NO ₂ | Oxygen Balense: CO ₂ % CO % | -56 -19 |
| и 32.6 н ₂ и | NH ₂ | Ecosity: gm/cc Crystal | 1.93 |
| 0 37.2 | NO ₂ | Melhing Point: °C 330 (b, e) | 360 (a) |
| C/H Ratio 0-302 | - | Freezing Point: *C | |
| Impact Sonsitivity, 2 Kg Wt: | | Beiling Paint: *C | |
| Bureau of Mines Apparatus, cm Somple Wt 20 mg Picatinny Arsenal Apparatus, in Sample Wt, mg | 11 7 | Refrective ludes, nº nº nº nº nº nº nº nº nº nº nº nº nº | |
| Friction Pendulum Test: Steel Shoe Fiber Shoe | | Vecuum Strhillity Test: cc/40 Hrr. at 90°C | |
| Riffe Buller Impact Test: Trials % | • | 100°C (a, b) 120°C 135°C | 0.36 |
| Explosions Partials | | 150°C | **** |
| Burned Unaffected | | 200 Gram Bomb Sand Toot: Sand, gm | 42.9 |
| Explesion Temperature: *C Seconds 0.1 (no cop used) 1 5 10 | - | Sensitivity to Initiation: Minimum Detonating Charge, gm Mercury Fulminate Lead Azide Tetryl | 0.30 |
| 15 20 | | Prilistic Mexter, % TNT: | |
| | | Trough Took, % FNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | | Plate Dest Test: Method | |
| 100°C Heat Test: | | Condition | - |
| % Loss, 1st 48 Hrs | 0.00 | Confined | |
| % Loss, 2nd 48 Hrs | 0.00 | Density, gm/cc Drisonce, % TNT | |
| Explosion in 100 Hrs | None | | |
| Flammability Index: | | Detenation Rate: | None Pressed |
| Hygrenee, leity: % | | Charge Diameter, in. | 0.5 |
| Yeletility: | | Density, gm/cc Rate, meters/second | 1.60 -7500 |

AMCP 766-17

| Programmation Test: | Shaped Charge Effectiveness, TN | ľ = 100: |
|---|---------------------------------------|-----------------------|
| 90 mm 162, MF1 Projectio, Let WC-01: | Glass Cones S | iteel Cones |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total Ha. of Fragments: | Colors | Yellow |
| For TNT . | | 141104 |
| For Subject HE | Principal Uses: | |
| 3 Inch ME, MARAT Frejectile, Let ICC-5: | | |
| Density, gm/cc | | |
| Charge Wt, Ib | | |
| Total He. of Fregments: | Method of Loading: | Presso |
| For TINT | · · · · · · · · · · · · · · · · · · · | Presso |
| For Subject HE | | |
| | Leeding Dunelty: gm/cc | _ |
| Fragingat Valority: ft/sec | At 50,000 pai | 1.80 |
| At 9 ft At 25½ ft | | |
| | Storege: | |
| Density, gm/cc | Method | Dry |
| Plast (Relative to THT): | Hozard Class (Quantity-Distance | •) |
| Aire | Compatibility Group | |
| Peak Pressure | | |
| Impulse | Exudation | |
| Enurgy | | |
| Alt, Confined: | Detonation Velocity: | (a, b. c) |
| Impulse | Deneity on/on | Matana / sida |
| - | Density, gm/cc | Meters/sec |
| Under Weter | 1.290 | 5 380 |
| Peak Pressure | 1.345 1.675 | 56 2 8 6550 |
| Impulse | 1.575 | 6575 |
| Energy | 1.882 | 7035 |
| Underground: | 1.835 | 7223 |
| Peak Pressure | Heat of: | |
| Impulse | - | |
| Fnergy | Explosion, cal/gm | 2831 |
| | | |
| | | |

1,3,5-Triamino-2,4,6-Trinitrobensene (DATES)

Preparation:

(a)

Absolute alcohol (200 milliliters) was saturated with associa and then 12.5 gm (0.028 mol) of 1,3,5-tribrono-2,4,6-trinitrobensene, prepared according to Hill (MAVOHO Report Ho. 3709, 2 February 1953), was added. The flask was stoppered and allowed to stand at room temperature for a day. Additional associa was bubbled into the mixture, which was then heated under reflux for thirty sinutes, filtered hot, and the insoluble product collected on a Buches funnel. The product was mashed with water, alcohol, and dried. The 4.7 gm of material recovered was recrystallised from nitrobensene.

A disadvantage of the above method was that it could not be used for the preparation of large quantities of TATES. Since it did not seen fearible to develop a new sethod of preparation, an investigation was made of the reported amination reactions (see <u>Origin</u> below). An attempt was made (Ref f) to find a modification which would produce high yields of a pure product. The process which evolved from this study may be summarized as follows (Ref 2): 1,3,5-trichlorobensene was nitrated "in one step" to 1,3,5-trichloro-2,4,6-trinitrobensene in 85% yield. The crude nitration product was aminated in benzene with ammonia gas so DiTES, in yields of at least 95%.

Origin:

TATUS was prepared for the first time in 1888 by C. L. Jackson and J. F. Wing, who f and the compound insoluble in alcohol, ether, chloroform, benzene, and g'acial acetic acid; and soluble in nitrobenzene and sniline (Amer Chem Journal 10, 262 (1868)). B. Flurscheim and E. L. Holmes prepared TATUS from benzene free pentanitromilline by gradually adding it to 10% aqueous amonia (J Chem Soc, Pt 2,30% (1926)). After boiling, an orange-yellow powder melting above 300°C was obtained. This product corresponded to that described by Jackson and wing. These authors, as well as Palmer (Amer Chem Journal 14, 378 (1892)), attempted to reduce TATUS to hem-sminobenzene. Rither decomposition occurred or a hydrochlorids of penta-aminobenzene was formed. Flursch. 4 and Holmes succeeded in reducing TATUS with pastagle-leasine by heating them together up to 200°C (J Chem Soc, Pt 1,334 (1929)) (Bril 12, 301 a.d EII, 147).

References:77

- (a) F. Taylor, Jr., Synthesis of May High Explosives II, Derivatives of 1,3,5-Tribromo-2,4,6-Trinitrobenzume, MAYORD Report No. 4405, 1 Movember 1956.
- (b) L. D. Hampton, Small Scale Detonction Velocity Measurements from May 1951 to May 1954, MAYORD Report No. 3731, June 1954.
- (c) E. M. Fisher and E. A. Christian, Explosion Effects Data Cheets, MAYORD Report No. 2986, 14 June 1955.

⁷⁷See footnote 1, page 10.

| CityONO2 | Welconfer Melalit: (CRITENSOE, | 240 |
|--|--|--------------|
| С 59.9 н ⁵ С | Oxygen Belenteu: CO2 % CO % | -89 -27 |
| H 11.7 | Dencity: gm/cc 20°C 25°C | 1:33 1:32 |
| 0 53.0 H ₂ C 0 | Mobiling Point: *C | |
| C/H Ratio 0.17; H ₂ C CH ₂ ONO ₂ | Preexing Point: 'C | |
| Respect Sensitivity, 2 Kg Wit: Stureou of Mines Apparetus, cm 100+ | Bulling Point: *C | |
| Somple Wt 20 mg Picotinny Asserol Apparatus, in. 43 Sample Wt, mg | Refrective Index, no. no. no. | 1.4540 |
| Frietlen Pendulum Test: | Vecuum Stebility Test: | |
| Shed Shee Unaffected Fiber Shee Unaffected | cc/40 Hrs, at 90°C | |
| Riffe Bullet Impact Test: Trials | 100°C 8 hours | 0.45 0.8 |
| C % Explosions | 135°C | 0.0 |
| Portiols | 150°C | |
| Burned | 200 Gram Bomb Sand Test: | |
| Unaffected | Sond, gm | 14.7 |
| Explosion Temperature: *C Seconds, 0.1 (no cop used) | Sensitivity to Initiation: Minimum Detonating Charge, gm | |
| 1 5 223 | Mercury Fulminate | |
| 10 | Lead Azide Tetryl | |
| 15 | | |
| 20 | Ballistic Merter, % TNT: | |
| 75°C International Heat Test: | Treuzi Test, % TNT: | |
| % Loss in 48 Hrs | Plate Dent Test: Method | |
| 160°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs 1.8 | Confined | |
| % Loss, 2nd 48 Hrs 1.6 | Density, gm/cc Brisance, % TNT | |
| Explosion in 100 Hrs None | | |
| Flemmubility Index: | Detenation Rate: Confinement | Shelby steel |
| | Condition | Liquid |
| Hygrescepicity: % | Charge Diameter, in. | 1.25 |
| Valuabley: 60°C, mg/cm²/hr 40 | Density, gm/cc | 1.33 |
| Valuability: 60°C, mg/cm²/hr 40 | Rate, meters/secund | Fails |

Triethylene Glycol Dinitrate (TEGN) Liquid

| | * | * * . | | | |
|--|---|-----------------------------|----------------|---------------|--------------|
| Fragmentation Test: | | Shoped Charge | Effectiveness, | TNT = 100: | |
| 90 mm HE, M71 Projectile, Let WC-91: | | | Glass Cones | Steel Cones | |
| Density, gm/cc | | Hale Volume | 1 | | |
| Charga Wt, Ib | | Hole Depth | | | |
| Total No. of Fragments: | F | Color: | | | |
| For TNT | | | | | |
| For Subject HE | - | Principal Uscs: | Ingredient | of rocket and | double |
| 3 inch HE, M42A1 Projectile, Let KC-5: | i | • | base prope | | |
| Density, gm/cc | l | | | | |
| Charge Wt, Ib | | | | | |
| Total No. of Fragments: | , , <u>, , , , , , , , , , , , , , , , , </u> | | | | |
| For TNT | | Method of Load | ling: | | |
| For Subject HE | | | | | |
| - | | Looding Density | r: gm/cc | | |
| Fragment Volacity: ft/sec | | | | | |
| At 9 ft At 25½ ft | Γ | Storage: | | | |
| Density, gm/cc | [| _ | | | |
| | 1 | Method | | Liqu | ui1 d |
| Siest (Relative to TNT): | | Hazard Class | (Quantity-Dist | rance) | |
| Aire | | Compatibility | Group | | |
| Peak Pressure | 1 | | | | |
| Impulse | j | Exudation | | | |
| Energy | į. | a-1-1-11-1 | *** | | |
| Air, Confined: | | Solubility in gm/100 gm, at | | | |
| Impulse | 1' | 25°C | | 0.5 | 5 |
| | | 60°C | | 0.6 | |
| Under Weter: Peck Pressure | | Solubility, g | m/100 gm, | | |
| Impulse | | at 25°C, in: | | _ | |
| Energy | | Ether Alcohol | | ** | |
| | | 2:1 Ether:A | lcohol | • | |
| Underground: | | Acetone | | ~ | |
| Peak Pressure | 1 | Viscosity, ce | | | |
| Impulse | | Temp, 20°C | | 13. | 2 |
| Energy | | Hydrolysis, % | | | •• |
| Heat of: | | 10 days at 5 days at | 90₀C 55₀C | 0.0 | |
| | 428 | Vapor Pressur | | | |
| Explosion, cal/gm Gas Volume, cr/gm | 357 851 | o _C | _ | mm Merciu | r <u>y</u> |
| CAR TULING CITHE | | | | | |

Origin:

Lourence prepared triethylene glycol in 1863 by reading glycol with ethylene bromide in a sealed tube at 115°-120°C (Ann (3) 67, 275). Later in the same year Mirtz prepared triethylene glycol by heating ethylene oxide with glycol at 100°C. By action of nitric acid triethylene glycol was oxidized to (H2000°CH2°0°CH2) (Ann (3) 69, 331, 351).

The Germans and Italians were the first to prepare and use TEGN during World War II as an ingredient of rocket and propellant powders. The commercial production of TEGN in quantity is still difficult and its use as a plasticizer for nitrocellulose is being replaced by other liquid nitrates.

Preparation:

Triethylene glycol is purified by fractional distillation under vacuum in an 18-inch Vigeaux fractioning column. The assembly as a whole is equivalent to 4.5 theoretical plates. The distillation is conducted using a 5 to 1 reflux ratio, at a pot temperature of approximately 180°C, and a take-off temperature of approximately 120°C.

The purified triethylene glycol (TEG) is nitrated by carefully stirring it into 2.5 parts of 65/30/5 nitric acid/sulphuric acid/water maintained at 0 ± 5°C. The rate of cooling is sufficient that 300 gm of TEG can be added within 40 minutes. The mixture is stirred and held at 0 ± 5°C, for 30 additional minutes. It is then drowned by pouring onto a large quantity of ace and extracted three times with ether. The combined extract is water-washed to a pH of about 4, shaken with an excess of sodium bicarbonate solution, and further washed with 1% sodium bicarbonate solution until the washings are colorless. The ethersal solution is water-washed until it has the same pH value as distilled water. It is careful separated from excess water, treated with chemically pure calcium chloride to remove dissolved water, and filtered. The ether is removed by bubbling with dry air until a minimal rate of loss in weight is attained. The yield is 1.34 gm per gm TEG (84% of theoretical) and the nitrogen content of different batches range from 11.60 to 11.69% by the nitrometer method (calculated 11.67%).

References: 78

(a) See the following Picatinny Arsenal Technical Reports on TEGN:

| <u>3</u> | 5 | <u>6</u> | I | <u>8</u> |
|--------------|------|----------------------|--------------|----------|
| 1953 2193 | 1745 | 1786 205 6 | 1767 1817 | 1638 |

⁷⁸See footnote 1, page 10.

Trimonite

| Composition: | Melecular Weight: | 217 |
|---|-------------------------------|-------------|
| • | Oxygen Balence: | |
| Pierie Acid 88 - 90 | CO. % | -62 -14 |
| Mononitronaphthalene 12 10 | | |
| • | Dennity: gm/cc Cast | 1.60 |
| | Molting Point: *C | 90 |
| C/H Ratio | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: | Boiling Point: *C Explodes | 300 |
| Bureau of Mines Apparatus, cm 60 Sample Wt 20 mg | Refrective index, no | |
| Picatinny Arsenal Apparatus, in. 10 | | |
| Sample Wt, ring | n _a | |
| | n _s . | |
| Friction Pendulum Test: | Vocuum Stability Test: | |
| Steel Sale | cc/40 Hrs, at | |
| Fiber Shoe | 90°C | |
| Rifle Bullet Impact Test: Trials | 100°C | |
| % | 120°C | 0.9 |
| Explosions 0 | 135°C | |
| Portiols 0 | 150°C | |
| Burned 0 | 200 Grem Bomb Sond Test: | |
| Unaffected 100 | Sond, gm | 44.2 |
| | | **** |
| Explosion Temperature: "C Seconds, 0.1 (no cap used) | Sensitivity to Initiation: | |
| 1 | Minimum Detonating Charge, gm | |
| 5 Decomposes 315 | Marcury Fulminate | |
| 10 | Leod Azide | 0.20 |
| 15 | Tetryl | 0.04 |
| 20 | Ballistic Morter, % TNT: | |
| | Treusi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: | |
| | Method | |
| 186°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs | Confined | |
| % Loss, 2nd 48 Hrs | Density, gm/cc | |
| Explosion in 100 Hrs | Brisance, % TNT | · |
| Flommability Index: | Detenation Rate: | |
| rammeomsy (ACCA; | Confinement | None |
| Hygrecospicity: % | Condition | Cast |
| ту ргоосорган у: 70 | Charge Diameter, in. | 1.0 |
| | Density, gm/cc | 1.60 |
| Veletility: | | |

Trimonite

| Fragmontation Test: | Sheped Cherge Effectiveness, TNT = 10 |)O: |
|--|--|-----------------|
| 90 mm HE, M71 Projectile, Let WC-91: | Glass Cones Steel C | ones |
| Density, gm/cc | Hole Volume | |
| Charge Wt, Ib | Hole Depth | |
| Total No. of Fragments: | Calac | |
| For TNT | | |
| For Subject HE | Principal Uses: TNT substitute in | projectiles |
| 3 inch HE, M42A1 Projectile, Let KC-5: | and bombs | |
| Density, gm/cc | | |
| Charge Wt, lis | | |
| Terel No. of Fragments: For TNT | Method of Looding: | Cast |
| For Subject I-IE | | |
| | Leeding Dessity: gm/cc | 1.60 |
| Fragment Velocity: ft/sec | | |
| At 9 ft At 25½ ft | Storage: | |
| Density, gm/cc | | |
| | Method | Dry |
| Blast (Relative to TNT): | Hozard Class (Quantity-Distance) | Class 9 |
| Air: | Compatibility Group | Group I |
| Peak Pressure | _ | 0- |
| Impulse | Exudation Exc | des at 50°C |
| Energy | | |
| Air, Confined: | Preparation: | |
| Impulse | Picric acid and alpha-mononit | ronaphthalena |
| Under Water: | are melted together in an alumin | |
| Peak Pressure | Jacketed melt kettle equipped wi Although picric scid slone requi | res a high tem- |
| Impulse | perature for its melt loading (1 | 20°C), the |
| Energy | mixture forms a cutectic melting must be taken to prevent the for | mation of dan- |
| Underground: Paok Pressure | gerous metallic picrates. Trime interest as an emergency substit | mits is of |
| Impulse | | |
| Energy | | |
| | | |
| | | |
| | | |
| | | |

Trimonite

Origin:

Trimonite, a castable mixture of picric acid/mononitronaphthalene was developed by the British during World War II as an improvement over tridite which is a mixture of 80/20 picric acid/dinitrophenol. Both mixtures are suitable for melt-loading below 100°C and therefore represent an improvement over melt-loading picric acid alone (melting point 122°C). However, tridite is slightly inferior to picric acid as an explosive and dinitrophenol is objectionable because of its toxicity. Trimonite is also slightly inferior to picric acid and TMT as an explosive. Because of the low eutectic temperature of the picric acid-mononitronaphthalene mixture (49°C), Tridite exudes when stored at elevated temperatures. It does not possess the disadvantages of picric acid (corrosive action on metals, ease of decomposition, etc.) and is a comperatively inexpensive substitute for TMT.

References: 79

(a) See the following Picatinny Arsenal Technical Reports on Trimonite:

| 2 | <u>5</u> | <u>6</u> | <u>8</u> |
|------|----------|--------------|---------------|
| 1352 | 1325 | 9 2 6 | 1098 |
| 1372 | | 9 7 6 | 18 3 6 |

⁷⁹See footnote 1, page 10.

| Composition: | Melerator Weight: ((6H6N6014) | 3 66 |
|--|-----------------------------------|--|
| c 18.6 | Oxygen Belence: | |
| | CO ₃ % | -4.2 |
| H 1.6 . | CO % | 20. 8 |
| N = 21.8 $C = 0$ $C = 0$ | Density: gm/cc Form I | 1.78 |
| 0 58.0 | Melting Point: *C | 93 |
| C/H Rotio 0.202 CH2CH2C(NO2)3 | Freezing Point: *C | |
| Impact Sensitivity, 2 Kg Wt: | Beiling Point: *C | |
| Bureou of Mines Apparatus, cm Sample Wt 20 mg | Refrective Index, no Form I (e | <u>, </u> |
| Picatinny Arsenal Apparatus, in. | Crystal Axis | • |
| Sample Wt, mg | B | 1.518 1.5 27 |
| 50% point, cm (a) 20 | _ | 1.546 |
| Friction Fondulum Test: | Vacuum Stability Test: | |
| Steel Shoe | cc/40 Hrs, at | |
| Fiber Shoe | 90°C | |
| Diffe Bullet Language Tool | - 100°C 48 hrs | 0.60 |
| Riffe Bullet Impact Test: Trials | 120 C | |
| % Evaluations | 135°C | |
| Explosions | 150°C | |
| Portiols Burned | | |
| Burned | 200 Grem Bomb Send Test: | |
| Unaffected | Sand, gm | |
| Englission Temperature: | Sensitivity to Initiation: | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | |
| 1 | Mercury Fulminate | |
| 5 50% point (Alhot bar) (a) 225 | Leod Azide | |
| 10 | Tetryl | |
| 15 | | |
| 20 | Bellistic Morter, % TNT: (b) | 136 |
| 78°C International Mark Tast | Treuzi Test, % TNT; | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Deat Test: Method | |
| 160°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs | Confined | |
| % Loss, 2nd 48 Hrs | Density, gm/cc | |
| Explosion in 100 Hrs | Brisance, % TNT | |
| empressor in 199 file | | |
| Flammability Index: | - Datenation Rate: Confinement | |
| <u>·</u> | | |
| Hygrescapicity: % 30°C, 90% RH 0.00 75°C, 5 months N:1 (a) | Condition | |
| 75°C, 5 months N11 (a) | Charge Diameter, in. | _ |
| Voletility: | Density, gm/cc 1.60 | 1.76 |
| · = · = · · · · · · · · · · · · · · · · | Rate, meters/second 7760 | 8 290 |

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TNETB)

| Boostor Sensitivity | Test: | | Decomposition Equation: | |
|-------------------------------------|---------------------------------------|------|---------------------------------|------------------------|
| Condition | | | Oxygen, atoms/sec (Z/sec) | 4.4 x 10 ²¹ |
| Tetryl, gm | | | Heat, kilocalurie/mole | 43.4 |
| 'Nax, in. for 509 | 6 Detonation | | (AH, kcal/mol) | J . |
| Wax, gm | | | Temperature Range, °C | |
| Density, gm/cc | | | Phase | Liquid |
| Heat of: Combustion, cal/ | · · · · · · · · · · · · · · · · · · · | 1685 | Armer Plate Impact Test: | |
| Explosion, cal/gr | • | 2007 | | |
| | | | 60 mm Morter Projectile: | |
| Gas Valume, o | • | 207 | 50° Inert, Velocity, ft/sec | ` |
| Formation, cal/g | 771 | 307 | Aluminum Fineness | |
| Fusion, cai/gm Sublime+lou, | cal/gm (c.t) | 804 | 500-lb General Purpose Bombs: | |
| Specific West: cal/g | gm/°C | | Plate Thickness, inches | |
| | | | 1 | . , |
| | | | 1 ' | |
| | | | 114 | |
| | | | 11/2 | |
| Russian Pater | | | 134 | |
| Burning Rate: cni/sec | | | | |
| | ······ | | Somb Drop Test: | |
| Thermal Conductivi cal/sec/cm/*C | ity: | | T7, 2000-lb Semi-Armor-Plercing | Bomb vs Concrete: |
| Coefficient of Exper | esion• | | Max Safe Drop, ft | |
| Linear, %/°C | | | 500-lb General Purpose Bomb vi | Concrete: |
| Volume, %/°C | | | Height, ft | |
| Maniness Make! #- | | | Trials | |
| Herdness, Mohs' Sc | UN: | | Unaffected | |
| Young's Modulus: | | | Low Order | |
| E', dynes/cm² | | | High Order | |
| E, lb/inch² | | | | _ |
| Density, gm/cc | | | 1000-lb General Purpose Bomb v | s Concrete: |
| | | | Height, ft | |
| Compressive Strong | M: Ib/inch² | | Trials | |
| | | · | Unaffected | |
| Vapor Pressure: | | (e) | Low Order | |
| ·c | mm Mercury | | High Order | |
| 65 75 | 3.3 x 10 1 | | | |
| 75 85 | 1.3 x 10 1 4.2 x 10 | | | |
| 1.00 | 4.2 x 10 3 2.3 x 10 3 | | | |
| ***** | 1.4 x 10 ⁻² | | | |

| Fregmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | |
|--|---|--|--|
| 90 mm HE, M71 Projectile, Let WC-97: | Glass Cones Steel Cones | | |
| Density, gm/cc | Hole Volume | | |
| Charge Wt, Ib | Hole Depth | | |
| Total No. of Fregments: | Coloriess | | |
| For TNT | | | |
| For Subject HE | Filacipal Uses: | | |
| 3 inch HE, M42A1 Projectile, Lc? KC-5: | | | |
| Density, g:m/cc | | | |
| Charge W ₇ , ib | | | |
| Total No. of Fragments: | Method of Looding: | | |
| For TNT | ; | | |
| For Subject HE | Leeding Density: gm/cc Form I 1.783 | | |
| Fregment Velocity: fr/sec | Form II 1.677 | | |
| At 9 ft At 25½ ft | Liquid, 99°C, 1.551 Storage: | | |
| Density, gm/cc | Method Wet | | |
| Sheet (Relative to H-62: Sphere Cylinder (h) | Hazará Class (Quantity-Distance) Compatibility Group Exudation | | |
| Energy | | | |
| Air, Confined: impulse Under Weter: Peok Pressure | Bruceton Safety Test Results: (g) Mean and standard deviation of lengths of 0.300 diameter cylinder across which initia- tion is possible for 50% certainty: | | |
| Impulse | TNT 0.391 + 0.640 | | |
| Energy | RDX Comp B 0.361 7 0.042 EXETB 0.920 7 0.059 | | |
| Underground: Peak Pressure | Absolute Viscosity, poises: (e) | | |
| Impulse | Temp, 98.9°C 0.173 | | |
| Energy EW, equivalent weight of H-6 fex a unit weight of test mixture for equal performance at the same test distance; EV, equivalent volume of H-6 for a unit volume of test mixture for equal performance at the same test distance. | 1.06.5°c 0.13 8 | | |

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TMETB)

Solubility (Room Temperature):

| ì | _ | • |
|---|---|---|
| £ | 2 | |

| Solvent | Solubility | |
|--|---|--|
| Nater n-Hamne Carbon tetrachloride Ethanol Chloroform Bersene Nitromethano Glacial &cetic acid Ethyl acetate | Insoluble Insoluble Insoluble Insoluble 5 gm/100 gm solvent 5 gm/100 gm solvent 10 gm/100 gm soivent Very soluble Very soluble Very soluble | |

TMETS Forms Entectics With the Following Compounds: (a)

| BRES (bis(trinitroethyl) succinete) BRES (bis(trinitroethyl) nitramine) THE (trinitroetzene) | 57 80+ 68.5 65 | |
|--|-------------------------|---|
| Compound A (ChHcHhO, formed by condensation of 1,1-dinitroethane) Trinitroethyl trinitrobenzoate (27%) | 77 80.5 (£) | ; |

Crystallographic Data:

(a)

Three polymorphic crystalline forms have been observed. Low temperature Form I goes through a solid-solid transition at 89°C giving Form II. Form II has a melting point of 92.5° to 93°C. On cooling, Form II does not transform reversibly to Form I when 89°C is reached. However, Form II will transform to Form I at room temperature, usually taking a few hours to do so. Form III was observed, which appeared to be stable over a vary narrow temperature range on the order of 0.2° to 0.3°C near 92.5°C.

Preparation:

(d)

| | | (-) | • |
|---|--|-------------------|---|
| (NO ₂) ₃ CCH ₂ CH ₂ COC1 + | (NO ²) 3CH ² OH | H250 ¹ | |
| trinitrobutyryl chloride | trinitroethanol | sulfuric acid | |
| | | | |

(No₂) 3 CCH2 CH2 COOCH2 C(No₂) 3

HCl

2,2,2-trinitroethyl-4,4,4-trinitro- hydrochloric butyrate acid

Laboratory experiments indicate that the present slow step involving overnight treatment of 4,4,4-trinitrobutyryl chloride with 2,2,2-trinitrobuthanol and aluminum chloride can be replaced by a fast and simple esterification in sulfuric acid. Using 100% sulfuric acid of fortified H₂SO₆, the ester can be prepared in yields of 95% to 93% in 24 hours at 25°C, in 5 hours at 50°C, or in 3 hours at 65°C. Above 65°C the reaction time is less, but the yield falls off and a less pure product is obtained. The crude white crystalline product on recrystallization from dilute methanol gives a material melting at 92° to 93°C.

2,2,2-Trinitroethyl-4,4,4-Trinitrobutyrate (TMETE)

Origin:

(_)

THESE belongs to a new class of explosives characterized by trinitromethyl groups,

-C(Mo₂)₂. The chemistry of this class of compounds was studied in Germany by Drs. Schenck and Softwalschmidt, who discovered in 1942-1945 at trinitromethene or nitroform, MC(Mo₂)₃, was the source of new explosive derivatives. Dr. Schenck prepared the stable solid alcohol, 2,2,2-trinitroethanol, from nitroform and formuldehyde. Dr. Schimmelschmidt reacted nitroform with unsaturated organic compounds, such as acrylic acid, and predicted in 1943 that the exter of 4,4,4-trinitrobutyric acid with trinitroethanol would be an interesting explosive.

In 1947 the U.S. Havy began a program to explore these comporties. The initial task of investigating the chemistry of trinitroethenol was undertaken by the Hercules Powder Company (Many Contract Mord-19,129). The U.S. Rubber Company studied the chemistry of nitroform (Many Contract Mord-10,129). After preparation of the first laboratory samples of TMETB, considerable interest was aroused. In early 1950 the Mangatuck Chemical Division of U.S. Rubber Company was assigned to prepare 100 pounds of TMETB. The Bureau of Ordnance in July 1953 reised the production to 800 pounds with the assistance of the Hercules Powder Company in aug. ing the production at Brugatuck (Havy Contract Mord-11,280). TMETB is a high oxygen content explosive.

References: 80

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- (b) Bureau of Mines Report No. 3107, Part IX, Ballistic Mortar Tests on Trinitrouthyl Trinitrobutyrate, 5 April 1950.
- (c) L. D. Hampton and G. Svadeba, Evaluation of 2,2,2-Trin troothyl-4,4,4-Trinitrobu', whe at a Constituent of Castable Explosives, MAVCHD Report No. 261, 30 September 1952.
- (d) U.S. Rubber Company Quarterly Progress Report No. 23, 9/nth-sis of New Propellants and Explosives, New Contracts Nord-10-129 and -12,663, 19 August 1/53.
- (e) M. B. Hill, O. H. Johnson, J. M. Rosen, D. V. Sickman and F. Taylor, Jr., Preparation and Properties of TMETB, a New Castable High Explosive, HAVORD Report No. 3885, 27 January 1955.
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- (g) Jacob Savitt, A Sensitivity Test for Castable Liquid Explosives, Including Results for Some New Materials, MAYORD Report No. 2997, 22 October 1953.
- (h) R. W. Gipson, Sensitivity of Explosives, IX: Selected Physico-Chemical Data of Men Pure High Explosives, MAVORD Report No. 6130, 18 June 1958.

⁸⁰See footnote 1, page 10.

Trinitro Triazidobenzene

| Comprolition: 06 | Melecular Weight: - (C606N1S) 336 | | | |
|---|-----------------------------------|--|--|--|
| NO ₂ | Gaygon Rolences | | | |
| 20 20.4 人 | CO ₂ % -29 | | | |
| N 50.0 N ₃ N ₃ | CO % U.0 | | | |
| 0 11 - 110 | Stemeity: gm/cc Crystal 1.81 | | | |
| Ψ | Melting Point: °C Decomposes 131 | | | |
| C/H Ratio | Freezing Paint: 'C | | | |
| Impact Sanitrivity, 2 Kg Wt: | Rolling Point: 'C | | | |
| Bureou of Mines Apparatus, cm (a) ≤ 25 | Beforethe Index B | | | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in | Refrective Index. no | | | |
| Sample Wt, mg | nº ` | | | |
| | n _s | | | |
| Friction Pondulum Test: | Vocuus Stability Tost: | | | |
| Steel Shoe | cc/40 Hrs, at | | | |
| Fiber Shoe | 90°C | | | |
| | — 100°C | | | |
| Riffe Bullet Impact Test: Trials | 120°C | | | |
| % | 135°C | | | |
| Explosions | 150°C | | | |
| Porticit | 130 C | | | |
| Burned | 200 Green Bomb Sand Test: | | | |
| Unaffected . | Sand, gm | | | |
| Explosica Temperature: *C (a) | Sociality to Initiation: | | | |
| Seconds, 0.1 (no cap used) | Minimum Detonating Charge, gm | | | |
| * | Mercury Fulminate | | | |
| 5 150 | Lead Azide | | | |
| 10 | Tetryl | | | |
| 15 | 1 di 1 yi | | | |
| 20 | Sellistic Morter, % TNT: | | | |
| | Treuzi Test, % PFIN: 90 | | | |
| 75°C International Host Test: % Loss in 48 Hrs | Plate Deat Test: Method | | | |
| 3846 11 - 2 | Condition | | | |
| 100°C Heat Test: | Confined | | | |
| % Lass, 1st 48 Hrs | Density, gm/cc | | | |
| % Loss, 2nd 48 Hrs | Brisance, % TNT | | | |
| Explosion in 100 Hrs | | | | |
| Resmobility Index: | Detenation Rate: | | | |
| rion/mounty index: | Confinement | | | |
| Hyprescepicity: % 30°C, 90% RP 0.00 | Condition | | | |
| Hygrescepicity: % 30°C, 90% RP 0.00 | Charge Diameter, in. | | | |
| No. 4 addis. | Density, gm/cc | | | |
| Voletility: | Rate, meters/second | | | |

Trinitro Triazidobenzena

| Fregmentation Test: Shaped Charge Effectiveness, TNT = 100: | | | | |
|--|---|---|--|--|
| 90 mm His, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Gloss Cones Steel Cones Hole Volume Hole Depth | | | |
| Total No. of Fregissets: For TNT | Color: Greeni | sh-yellow | | |
| For Subject HE | Principal Uses: (c) Ingredien | t of primer wix | | |
| 3 inch NE, M42A1 Projectile, Let KC-5: Darsity, gm/cr. Charge Wt, Ib | | | | |
| Total No. of Fragments: For TNT For Subject HE | Method of Leading: Dead presses at about 42, | Fressed COO psi | | |
| Fregment Velocity: ft/sec | Leading D salty: gm/cc At h2,000 psi | 1.75 | | |
| At 9 ft At 25½ ft | Storage: | | | |
| Density, gm/cc | Method | | | |
| Blast (Relative to TNT): | Hazard Class (Quantity-Distance |) | | |
| Air: Peok Pressure Impulse | Compatibility Group Exudation | None | | |
| Energy Air, Confined: Impulse | Qualitative Solubilities at Room 'emperature; Solvent | Solubility | | |
| Under Water: Peak Pressure Impulse | Acetone Chloroform Alcohol Water | Readily soluble Moderately soluble Sparingly soluble Insoluble | | |
| Energy | Compatibility with Metals: | | | |
| Undorgreund: Peak Pressure | Wet: Does not attack ire | on, steel, copper | | |
| Impulse | Heat of: | | | |
| Energy | Combustion, cal/gm (| 2554 | | |
| | Burning Rate: (1 | b) | | |
| | cm/sec | 0.65 | | |

Preparation: (e)

Aniline is chlorinated to form trichlomosniline. The amino group is eliminated by the disco reaction. The resulting typ-trichlorobenzene is nitrated. This nitration is carried out by dissolving the material in warm 32% cleam, adding strong mitric acid, and heating to 140°-150°C until no trinitro trichlorobenzene (melting point 187°C) precipitates (Ref f). The chlorine groups are then replaced by azo groups. This is accomplished by adding at accompanion of the trinitro trichlorobenzene, or better, and polered substance alone, to an actively stirred solution of sodium saide in alcohol. The precipitated trinitro triasidobenzene is collected on a filter, washed with alcohol, water and dried. It may be purified by dissolving in chloroterm, allowing the colution to cool, and collecting the greenish yellow crystals (melting point 131°C with decorposition).

Origin:

This initiating explosive was first prepared in 1923 by Turek who also perfected its manufacture.

References:81

- (a) S. Helf, Tects of Explosive Compounds Submitted by Arthur D. Little, Inc., PATR 1750, 24 October 1949.
- (b) A. r. Belyaeva and A. E. Belyaeva CR a.s. USSR 52, 503-505 (1946) Chemical Abstracts 41, 4310.
 - A. E. Belyaeva and A. F. Belyaeva, Doklady Akad Mauk. USSR 56, 491-494 (1947).
 - (c) French Patent 893,941, 14 November 1944 (Chemical Abstracts 47, 8374).
- (d) A. D. Yoffe, "Thermal Decomposition and Explosion of Azides," Proc. Roy Soc A208, 188-199 (1951).
- (e) T. L. Davis, The Chemistry of Fewder and Explosives, John Wiley and Sons, Inc., New York (1943), p. 436.
 - (f) O. Turek, Chim et Ind 26, 781 (1931); German Patent 498,050; British Patent 298,981.

⁸¹See footnote 1, page 10.

| Comparistons | Molecular Weight: (C ₁₅ H ₂₄ H ₈ O ₂₆) | 732 |
|---|---|--|
| Č 24.6 H 3.3 H 15.3 O 56.6 | Oxygen Beloree: CO ₂ % CO % | -5:5 -32 |
| ්ස් රහර ^ප ්ස් රහර ප් රහර | Density: gm/cc Crystal | 1.58 |
| Opinicas care care | Mobing Point: °C 82 | to 84 |
| C/H Rotto 2/1/2 | Freezing Point: *C | |
| Surgest Sassitivity, I No Wit. Burgest of Miner Apporatus, cm | Boiling Point: *C | |
| Sample Wt 20 mg Picatinny Arsenel Apparatus, in. 9 Sample Wt, my 24 | Refrective Index. no. no. no. no. no. no. no. no. no. no | |
| Friction Pendulum Test: | Yacuum Stobility Test: | · · · · · · · · · · · · · · · · · · · |
| Steel Shoe Unaffected | cc/40 Hrs, at | |
| Fiber Shoe Unaffected | 90°C | |
| Riffe Buffet Impost Test: Trials | 100°C Pure | 2.45 |
| % | 120°C Specially purified | 1.94 |
| Explosions | 135°C | |
| Porticis | 150°C | |
| Burned Unoffected | 200 Gram Bomb Sand Tost: Sand, gm | 58.9 |
| Emphalan Temporature: 'C | Sensitivity to Initiation: | |
| Seconds, 0.1 (nc cap used) | Minimum Detonating Charge, gm | |
| | Mercury Fulminate | |
| 5 225 | Lead Azide | 0.30 |
| * 10 · | Tetryl | |
| 15 20 20 | Bellistic Merter, % TNT: | ······································ |
| | Treezi Test, % TNT: | |
| 75°C International Heat Test: % Loss in 48 Hrs | Plate Dent Test: Method | |
| 100°C Heat Test: | Condition | |
| % Loss, 1st 48 Hrs 1.15 | Confined | |
| % Loss, 2nd 48 Hrs 0.75 | Density, gm/cc | ζ, |
| Explosion in 100 Hrs None | Brisance, % TNT | ` |
| Flammability Index: | Detenation Rate: | _ |
| | Confinement | None |
| Hyprescopicity: % | - Condition | Pressed |
| | Charge Diameter, in. | 0.5 |
| Volentiley: | Density, gm/cc | 1.56 |
| | Rate, meters/second | 7650 |

Tripentaerythritol Octanitrate (TPEON)

| • | Desemposition Equation. Oxygen, atoms/sec | |
|-------------|--|--|
| - | | |
| | Heat, kilocolorie/mole | 23.1 |
| | (AH, kcel/mol) | 015 4- 050 |
| | 1 - | 215 to 250 |
| | Phose | Liquid |
| 2622 | Armer Plate Impact Test: | |
| - | | |
| | 60 mm Morter Projectile: | |
| ios | 1 | |
| | Aluminum Fineness | |
| | 500-th General Purpose Bombs: | |
| | Plate Thirkness inches | |
| | rigite (frictions), inches | |
| 240 | 1 | |
| | 11/4 | |
| | 11/2 | |
| | 1% | |
| | | |
| | Somb Drop Yest: | |
| | T7 2000 th Sand Arman Standa | a Ramb us Canantas |
| | 17, 2000-11 20110-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1- | A marrie at Admirald; |
| | Max Safe Drop, ft | |
| | 500-lb General Purpose Bomb v | es Concrete: |
| | Height, ft | |
| | Trials | |
| | Unaffected | |
| | Low Order | |
| • | | |
| | | |
| | 1000-th General Purpose Semb | rs Concrete: |
| | | |
| | * · | |
| | 1 | • |
| | | |
| | | |
| | High Order | |
| | | |
| | | |
| | 2632 1085 762 | (Z/sec) Heat, kilocolorie/mole (AH, kcal/mol) Temperature Range, *C Phose 2632 1085 762 40 mm Marter Projectile: 50% inert, Velocity, fr/sec Aluminum Finaness 500-th General Purpose Bambs: Plate Thickness, inches 240 1 11/4 11/2 11/4 11/2 11/4 11/6 11/6 Remb Drep Yest: T7, 2000-th Semi-Armer-Piercia Max Safe Drop, ft 500-th General Purpose Bemb v Height, ft Trials Unaffected Low Order High Order |

Tripentaerythritol Octanitrate (TPEON)

| Fragmontation Test | Shaped Charge Effectiveness, THT = 100: | | |
|---|--|--|--|
| 90 mm HE, M71 Projectile, Let WC-91: Density, gm/cc Charge Wt, Ib | Glass Cones Steel Cones Hole Volume Hole Depth | | |
| Total No. of Fragments: For TNT | Color: White | | |
| For Subject HE 3 inch HE, M42A1 Projectile, Let KC-3: Density, gm/cc Charge Wt, ib | Principel Uses: High explosive and as possible plasticizer for nitrocellulose | | |
| Total No. of Fragments: For TNT For Entire ME | Method of Leeding: Cast or pressed | | |
| Fregment Velocity: ft/sec | Leeding Deselty: gm/cc Pressed at 60,000 psi 1.565 | | |
| At 9 ft At,25½ ft Density, gm/cc | Storage: Method Dry | | |
| Stast (Relative to TNT): | Hazard Class (Quantity-Distance) | | |
| Air: Peak Pressure Impulse Energy | Compatibility Group Exudation None | | |
| Air, Confined: | Hygroscopicity, Gain or Loss in Wt, 1: | | |
| Impulse | Time, Hrs | | |
| Under Weter: Peak Pressure Impulse | <u>40 70 90</u> 24 -0.008 +0.01 +0.0 | | |
| Energy | 144 -0.04 -0.03 -0.02 192 -0.04 -0.02 | | |
| Underground: Peak Pressure Impulse | 216 -0.004 -0.01 +0.03 Solubility: | | |
| Energy | Solvent Solubility | | |
| | Water Insoluble Alcohol Soluble Chloroform Soluble Acetone, hot Very soluble Benzene, hot Very soluble | | |

Tripentaerythritol Octanitrate (TPEON)

Compatibility With Other High Explosives:

100°C Varuum Stability Test:

| | NIN | PETN | RDX | TPEON |
|--|------|------|------|-------|
| ml gas/40 hrs, 5 gm sample | 0.14 | 2.15 | 0.39 | 2.45 |
| ml gas/40 hrs, 5 gm sample of 50/50, TPEON/HE | 1.89 | 1.71 | 2.32 | |

Dipentaerythritol Hexanitrate (DPENN)-TPECN Fusions:

| * TPBON | \$ DPERN | Solidification Time, Days | MP, °C |
|---------|----------|---------------------------|---------------|
| 100 | o | _ | 83 |
| 95 | ; 5 | 3 | 68 |
| 90 | 10 | 3 | 69 |
| 80 | 20 | 5 | 73 |
| 50 | 50 | 30 | 60 (Butectic) |
| 20 | 80 | 5 | 63 |
| 10 | 90 | 3 | 69 |
| 0 | 100 | | 73 |

Preparation:

(a)

Twenty grams (0.054 mol) of nitration grade tripentserythritol (TPE) (99%) minimum purity) were slowly added, with stirring, to 160 gm (2.55 mol) of 99% nitric acid at a temperature of -25° to 0°C. On equivalent weight basis, this quantity of 99% nitric acid corresponds to an excess of 6.3 times the TPE used. After addition of the TPE, the reaction mixture was stirred for about one hour at 0° to 5°C and poured into eight times its volume of cracked ice. The product, when allowed to stand overnight, was crushed under water; filtered with suction; and washed copiously with water. It was then treated twice with about 5 times its weight of a 1% ammonium carbonate solution, stirred for several hours, filtered and washed with water until the final washings were neutral to litrus. The final product was washed successively with 50 carach of ethanol and ether. The material dried in air weighed 37.8 gm or 96% of theory based on TPE. It had a melting range of 71° to 74°C. Crystallization of the crude TPEON from chloroform was found to be the most suitable method of obtaining pure TPEON.

Omigin:

TPEON prepared by the reaction of tripentaerythritol and 99% nitric acid at 0° to 10° C was reported by Wyler in 1945 (J. A. Wyler to Trojan Powder Company: U.S. Patent 2,389, 228, 20 November 1945).

Tripentaerythritol Octanitrate (TPEON)

References: 82

- (e) J. J. LaMonte, H. J. Jackson, S. Livingston, L. B. Silberman and M. M. Jones, The Preparation and Explosive Properties of Tripentaerythritol Octanitrate, PATR No. 2490, 1958.
- (b) K. Hamba, J. Yamashita and S. Tanaka, "Pentserythritol Tetranitrate," J Ind Explosives Scc (Japan) 15, 282-9 (1954); CA 49, 11283 (1955).
 - (c) S. D. Brewer and H. Henkin, The Stability of PETM and Pentolite, OSRD Report No. 1414.
- (d) E. Berlow, R. H. Barth and J. E. Snow, <u>The Pentaerythritols</u>, ACS Monograph No. 136, Reinhold Publishing Corporation, New York, 1958.

⁸²See footnote 1, page 10.

| Composition: | Melecular Weight: | 81 | | |
|---|--------------------------------------|-------------|--|--|
| % TNT 80 | Oxygen Belence: | | | |
| | CO, % | -77 -38 | | |
| Aluminum 20 | | | | |
| | Density: gm/cc Cast | 1.72 | | |
| | Molting Faint: *C | | | |
| C/H Ratio | Freezing Point: *C | | | |
| Impact Sensitivity, 2 Kg Wt: Burecu of Mines Apparatus, cm 85 | Boiling Point: °C | | | |
| Sample Wt 20 mg | Refrective Index, no | | | |
| Picotinny Arsenal Apparatus, in. 13 Sample Wt, mg 16 | n≗ | | | |
| Somple VII, III | n _s | | | |
| Friction Pendulum Test: | Vecuum Stebility Test: | | | |
| Steel Shoe Unaffected | cc/40 hirs, at | | | |
| Fiber Shoe Unaffected | . 60.€ | | | |
| Riffe Bullet Impact Test: Trigis | 100°C | 0.1 | | |
| • | 120°C | 0.2 | | |
| % Explosions 60 | 135°C | | | |
| Partials 0 | 150°C | 0.8 | | |
| Burned 0 | 200 Gram Bomb Sand Test: Sond, gm | | | |
| Unaffected 40 | | | | |
| Explosion Temperature: 'C | Sensitivity to Initiation: | | | |
| Seconds, 0.1 (no cap used) 610 | Minimum Detonating Charge, gm | | | |
| 1 520 5 December 1/20 | Mercury Fulminate | | | |
| 5 Decomposes 470 | Lead Azide | 0.20 | | |
| 10 465 | Tetryl | 0.10 | | |
| 15 20 | Ballistic Morter, % TNT: (a) | 124 | | |
| | Trousi Test, % TNT: (b) | 125 | | |
| 75°C International Heat Test: | Plate Dest Test: (c) | | | |
| % Loss in 48 Hrs | Method | В | | |
| 160°C Heat Test: | Condition | Cast | | |
| % Loss, 1st 48 Hrs | Confined | No | | |
| • | Density, gm/cc | i.75 | | |
| % Loss, 2nd 48 Hrs | Brisonce, % TNT | 93 | | |
| Explosion in 100 Hrs | Decemetion Rate: | | | |
| Floremobility Index: 100 | Confinement None | None | | |
| | Condition Cast | Pressed | | |
| Hygrescopicity: % 30°C, 90% RH 0.00 | Charge Diameter, in. 1.0 | 1.0 | | |
| | | | | |
| | Density, gm/cc 1.71 | 1.72 | | |

| Beaster Sensitivity Test: Condition | (d) | Cast | Decomposition Equation: Oxygen, atoms/sec | | |
|--|----------|-------------------------|--|---------------|---------------|
| Tetryl, gm | | 100 | (Z/sec) | | |
| Wax, in. for 50% Detanation 0.58 | | Heat, kilocalorie/mole | | | |
| · · · · · · · · · · · · · · · · · · · | gilon | 0.70 | (AH, kcai/mol) | | |
| Wox, gm | | 1.75 | Temperature Range, *C | | |
| Density, gm/cc | | 1.17 | Phase | | |
| Heat of: Combustion, cal/gm | (e) | 4480 | Armer Plate Impact Test: (| e) | |
| Explosion, cal/gm | | 1770 | 60 mm Merter Projectife: | | |
| Gas Volume, cc/gm | | | 5C% Inert, Velocity, ft/sec | 509 | >1100 |
| Formation, cal/gm | | | Aluminum Fineness | 100 | 12 |
| Fusion, col/gm | | | | | |
| | | | 500-lb General Purpose Bernb | : : | |
| Specific Heat: cal/gm/°C At -5°C | (b) | 0.23 | Plate Thickness, inches | Trials | ≸ Inert |
| Density, gm/cc | | 1.74 | 1 | 0 | |
| Dension, Sm/cc | | 2014 | 11/4 | • 6 | 100 |
| At 20°C | | 0.31 | 11/2 | 6 | 33 |
| | | | 13/4 | 0 | 33 |
| Burning Rate: cm/sec | | | Sorub Drop Test: (e) | | |
| Thormai Conductivity: cal/soc/cm/*C Density, gm/cc | (b) | 11 x 10 ⁻¹⁴ | 17, 2000-tb Semi-ArmsPierc | ing Somb vs | Concrete: |
| Coefficient of Expension: | | | Max Safe Drop, ft | | |
| Linear, %/°C | | | 500-lb General Purpose Bomb | vs Concrete | 12 |
| Volume, %/°C | | | 41.544.6 | Seal 4,000 | Seal 5.000 |
| | | | T . | | |
| Hardness, Mahe' Scule: | | | Tricls | 34 ~~ | 14 |
| | | | Unaffected | 32 | 14 |
| Young's Modulus: | (b) | | Low Order | 0 | 0 |
| E', dynes/cm² | . • | 6.67 x 10 ¹⁰ | High Order | 2 | 0 |
| E. Ib/inch² | | 0.97 x 10 ⁶ | | | |
| Density, gm/cc | | 1.72 | 1000-lb General Purpose Semi |) VI Contril | |
| | | | Height, ft | | Seal 5.000 |
| Compressive Strongth: lb/ir | rch² (b) | 2340 | Trials | | 24 |
| Density, gm/cc | | 1.75 | Unoffected | | 23 |
| | | . | - | | |
| Vepor Pressure: "C mm | Mercury | | Low Order | | 0 |
| C mm | rwercury | | High Order | | 1 |
| | | | | | |

| Fragmentation Test: | X | Shaped Charge Silectiveness, THY = 1 | 190: |
|-------------------------------------|--------------|---|---------------------------|
| 90 mm HE, M71 Projectile, Let WC | 9 1: | Glass Cones Steel | Cones |
| Dercity, sm/cc | 1.71 | Hole Volume | |
| Charge Wt, # | 2.272 | Hole Depth | |
| Total No. of Fragments: | | | |
| For TNT | ሃወ3 | Color: | Gray |
| For Subject HIE | 616 | | |
| 3 inch HE, M43A1 Projectile, Let KC | .E. | Principal Vers: GP bombs | |
| Density, gm/cc | 1.75 | | |
| Charge Wt, Ib | 0.914 | | |
| Yatul No. of Fragments: | | | |
| For TNT | 514 | Method of Londing: | Cast |
| For Subject HE | 485 | | |
| | | Leeding Dentity: 5m/:x | 1.65-1.72 |
| regment Velocity: ft/sec At 9 ft | 2460 | | |
| At 25% ft | 2460 2460 | Storees: | |
| Density, gm/cc | 1.72 | | |
| | | Method | Dry |
| feet (Relative to TNT): | (f) | Hazard Class (Quantity-Distance) | Class 9 |
| Aim | | Compatibility Graup | Group I |
| Peak Pressure | 110 | | Group 1 |
| Impulse | 115 | Exudation | |
| Energy | 119 | | |
| Air, Confined: | | Preparation: | |
| Impuise | 130 | Tritonal is prepared by adding | TMT and |
| Under Weber: | | aluminum senerately to a steem- | criteted meli |
| Paak Pressure | 105 | kettle equipped with a stirrer. the kettle and mixing of the ine | nesting of redients em |
| Impulse | 118 | continued until all the TMT is | elted. When |
| Energy | 12.9 | the viscosity of the mixture is satisfactory (about 85°C), the t | ritonal is |
| Underwend: | | poured into projectiles or bombs | the same as |
| Peck Pressure | 117 | TAT. | |
| Impuise | 127 | 1 | |
| Energy | 136 | | |
| спенду | 136 | | |

Origin:

The Addition of aluminum to increase the power of explosives was proposed by Recales in 1899 and patented by Roth in 1900 (German Patent 172,327). Some recent studies, directed towards establishment of the optimum amount of aluminum in the TET/Aluminum system, have shown that (1) the blast effect increases to a maximum when the aluminum content is 30% (Ref g); the brisance, as measured by the Sand Test, passes through a maximum at about 17% aluminum (Ref h); in Fragmentation Tests, no maximum is observed, additions of aluminum causing a decrease in efficiency over the entire range from 0% to 70% aluminum (Ref i); and (4) the rate of detonation of cast charges is continuously decrease? by additions of aluminum up to 40% (Ref j). For all practicel purposes it is concluded that the addition of 18% to 20% aluminum to TET improves its performance to a maximum. This conclusion is in agreement with that of British workers who measured performance of aluminized TWT-mixtures based on extensive Lead Block Test data (Ref k).

Tritonal, consisting of 80% TWT and 20% aluminum, was developed and standardized in the United States during World War II for use in bombs.

References:83

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 - (c) D. P. MacDougall, Methods of Physical Testing, OSRD Report No. 803, 11 August 1942.
- (4) L. C. Smith and S. R. Walton, A Consideration of RDX/Wax Mixtures as a Substitute for Tetryl in Boosters, NOL Memo 10,303, 15 June 1949.
 - (e) Committee of Div 2 and 8, MDRC, Report on HBN and Tritonal, OSRD Fo. 5406, 31 July 1945.
- (f) W. R. Tomlinson, Jr., Elast Effects of Bomb Explosives, PA Tech Div Lecture, 9 April 1948.
- (g) W. B. Kennedy, R. P. Arentzen and C. W. Tait, Survey of the Performance of TMT/Al on the Basis of Air-Blast Pressure and Impulse, OSRD Report No. 4649, Division 2, Monthly Report No. AEE-6, 25 January 1945.
- (h) W. R. Tomlinson, Jr., Develop New Hith Explosive Filler for AP Shot, PATR No. 1290, First Progress Report, 19 May 1943.
- (i) W. R. Tomlinson, Jr., <u>Develop New High Explosive Filler for AP Shot</u>, FATR No. 1380, Second Progress Report, 12 January 1944.
- (j) L. S. Wise, Effect of Aluminum on the Mate of Detonation of THT, PATR No. 1550, 26 July 1945.
- (k) Armament Research Dept, The Effect of Aluminum on the Power of Explosives, British Report AC-6437, May 1944 (Explosives Report 577/44).

⁸³See footnote 1, page 10.

Tritonal, 80/20

(1) Also see the following Picatinny Arsenal Technical Reports on Tritonal:

0 3 ½ 5 6 I 8 1530 1693 1444 1635 1956 1737 2138 1560 2353 2127

| Composition: | | Melecular Weight: | 261 | | |
|---|------------|--|-------------|--|--|
| ж них | 70.0 | Oxygen Belerce: | | | |
| Nitrocellulose (13.15% N) | 15.0 | CO ₂ % | -26 | | |
| Mi troglycerin | 10.7 | co % | | | |
| 2-Nitrodiphenylamine | 1.3 | Beneitus om /cc Proposit | 1 70 | | |
| Triacetin | 3.0 | Density: gm/cc Pressed 1.72 Melting Point: *C | | | |
| C/H Ratio | | | | | |
| | | Freezing Point: *C | | | |
| Import Sensitivity, 2 Kg Wt: Bureou of Mines Apparatus, cm | | Boiling Point: 'C | | | |
| Sample Wt 20 mg Picatinny Arsenal Apparatus, in. | | Refrective Index, no | | | |
| Sample Wt, mg | | n <u>B</u> | | | |
| • • • • | | n _∞ | | | |
| Friction Pendulum Test: | | Vocuum Stability Test: | | | |
| Steel Shoe | Unaffected | cc/40 Hrs, at | | | |
| Fiber Shoe | Unaffected | 90°C | **** | | |
| Rifle Builet Impact Test: Trials | | 100°C | 1.29 | | |
| | | 120°C 29 hours 1 | | | |
| % Explosions | | 135°C | | | |
| Portiols | | 150°C | | | |
| Burned | | 200 0 0 1 1 | | | |
| | | 200 Gram Bomb Sand Test: | | | |
| Unaffected | | Sand, şim | 66.4 | | |
| Explosion Temperature: "C | | Sensitivity to Initiation: | | | |
| Seconds, 0.1 (ric cap used) | | Minimum Detonating Charge, gm | | | |
| 1 | | Mercury Fulminate | **** | | |
| 5 | | Leod Azide | 0.30 | | |
| 10 | | Tetryl | | | |
| 15 20 | | Sellistic Morter, % TNT: | | | |
| | | Treezi Test, % TNT: | | | |
| 75°C International Heat Test: % Loss in 69 Hrs | | Plate Dent Test: | | | |
| M F099 III V 2 L112 | | Method | | | |
| 90 °C Heat Test: | | Condition | | | |
| % Loss, 1st 48 Hrs 0.28 | | Confined | | | |
| % Loss, 2nd 48 Hrs | 1.12 | Density, gm/cc | | | |
| Explosion in 100 Hrs | None | Brisance, % TNT | | | |
| | | Detenation Rate: | | | |
| Flommobility Index: | | Confinement | | | |
| | | Condition | | | |
| Hygroscopicity: % | | Chorge Diameter, in. | | | |
| N. 1 . 1911. | | Density, gm/cc | | | |
| Volatility: | | Rote, meters/second (calculated) | 8500 | | |

^{*}See footnote c. following page.

Veltex No. 448*

| Secretar Sensitivity Test: | | Decomposition Equation: | | |
|--|------------------------|---|--|--|
| Condition | | Oxygen, atoms/sec (Z/sec) | | |
| Tetryl, gm | | Heat, kilocalorie/mole | | |
| Wax, in. for 50% Detonation | | (AH, kcal/mol) | | |
| Wax, gm | | Temperature Range, *C | | |
| Density, gm/cc | | Phase | | |
| Heat of: | . 0050 | Armor Plate Impact Test: | | |
| Combustion, cal/gm | 2359 | | | |
| Explosion, cal/gm | 1226 | 60 mm Morter Projectile: | | |
| Gas Volume, cc/gm | | 50% Inert, Velocity, ft/sec | | |
| Formation, cal/gm | | Aluminum Fineness | | |
| Fusion, cal/gm | | | | |
| | | 500-lb Ganeral Purpose Bombs: | | |
| Compression at Rupture: \$ | 8.26 | Plate Thickness, inches | | |
| Work to Produce Rupture: | | | | |
| ft-1b/inch ³ | 9.62 | 114 | | |
| 1 C-10/ I Ren | 9.02 | 11/2 | | |
| | | 134 | | |
| Surning State: | | 174 | | |
| cm/sec | | Samb Drue Test: | | |
| | | | | |
| Thermal Conductivity: col/sec/cm/°C | | T7, 2000-ib Somi-Armor-Piercing Bomb vs Concrete: | | |
| | | Max Safe Drop, ft | | |
| Coefficient of Expansion: | | Max sale Drap, It | | |
| Linear, %/°C | | 500-lb General Purpose Bomb vs Concrete: | | |
| Volume, %/*C | | Height, ft | | |
| | | Trials | | |
| Herdness, Mehs' Scale: | | Unaffected | | |
| | | Low Order | | |
| Young's Modulus: | . 10 | High Order | | |
| | .24 x 10 ¹⁰ | | | |
| E, Ib/inch ² C. | . 35 × 10 ⁵ | 1000-lb General Purpose Bomb vs Concrete: | | |
| Density, gm/cc | | | | |
| Community Strength, th/inch2 | 2720 | Height, ft | | |
| Compressive Strongth: Ib/inch² | 2120 | Trials | | |
| | | Unaffected | | |
| Voper Pressure: | | Low Order | | |
| °C mm Mercury | | High Order | | |
| *Name assigned by Dr. Mar. M. Jo of PA; based on original develonames H. Veltman. | | , | | |

Veltex No. 448

| Fragmentation Test: | Shaped Charge Effectiveness, TNT = 100: | | |
|---|---|--|--|
| 90 mm HE, M71 Projectile, Let WG-91: DenLity, gm/cc Charge Wt, th | Glass Cones Steel Concs Hole Volume ' Hole Depth | | |
| Total No. of Fragments: For TNT | Color: Orange | | |
| For Subject HE 3 inch HE, M42A1 Projectile, Let KC-5: Density, gm/cc Charge Wt, Ib | Principal Uses: High mechanical strength machinable explosive | | |
| Total No. of Fragments: For TNT For Subject HE | Method of Loading: Pressed | | |
| Fragment Velocity: ft/sec At 9 ft | Leading Density: gm/cc At 6,700 psi 1.72 | | |
| At 25½ ft Density, gm/cc | Storage: Method Dry | | |
| Bleat (Relative to TNT): | Hazard Class (Quantity-Distance) | | |
| Air: Peak Pressure Impulse Energy | Compatibility Group Exudation None Machinability Excellent | | |
| Air, Confined: Impulse | | | |
| Under Weter: Peak Pressure Impulse Energy | | | |
| Underground: Peak Pressure impulse Energy | | | |
| | | | |

Preparation:

The preparation of this class of explosive compositions is illustrated by the method used for Veltex No. 448: Place 675 cc of water in a slurry kettle equipped with an agit tem. Add 5.85 gm of 2-nitrodiphenylamine and agitate for several minutes to obtain dispersion. Then add 93.7 gm of water-wet nitrocellulose (dry weight 67.5 gm) in small portions. Prise the temperature to 48°C and maintain this temperature, but continue the agitation. A mixture of 48.2 gm of nitroglycerin and 13.5 gm of triacetin is added over a 5-minute period, with the mixing continuing for an additional 10 minutes at 48°C. The INX (350 gm) is added over a 5-minute period with agitation continued for 30 minutes at 48°C. The slurry is cooled to room temperature and filtered. The filter cake is dried to a moisture contant between 8% and 12%. The incorporation of this mix is completed by rolling 50 gm portions at a temperature of approximately 90°C. The finished coll d is then preheated on a heat table at 60°C. Increments of 25 gm each are pressed at 670c psi for four minutes at 71°C. A cylinder is then built up by pressing together four 25 gm increments for a dwell time of 15 minutes.

Origin:

Veltex is the name given to a series of closely related nitrocellulose compositions prepared in 1957 at Picatinny Arsenal by the solventless process used for propellants. These compositions all contain a high percentage of solid high explosive. They were investigated to determinate the suitability of the Holtex type explosive developed by Hispano Suiza of Switzerland, France and Spain, but for which the composition was not reported (Ref a). Compositions similar to Veltex No. 448 and containing 60% to 80% HMX, with either nitroglycerin or triethyleneglycol dinitrate as colloiding agent for nitrocellulose, have also been prepared. In general these compositions showed lower heat stability than that of conventional high explosive compositions.

Reference: 84

(a) U.S. Air Intelligence Information Report IR-269-55, Holtex--Hispano Suiza Explosive, 4 May 1955.

⁸⁴See footnote 1, page 10.

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